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SUMMARY PILOT WATERSHED REPORT
GENESEE RIVER BASIN, NEW YORK

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The Genesee River was monitored for stream flow and a variety of water quality parameters under a program sponsored by PLUARG. An integrated sampling program was operated from March 1975 through June 1977. Twenty-eight stations covered the spectrum of land use, soil type and geologic development found in the watershed. Pollutants studied in detail were total phosphorus, suspended solids and chloride.

Results of the study suggest that water quality is not entirely dependent on land use; soil type, geology and geomorphology also have a strong influence on the amounts and forms of various pollutants transported by surface waters. Variations in river loading indicate that urban land is relatively more productive than agriculture for the parameters studied. Forested land is the least productive.

Transport of the several pollutants is variable within reaches and over the watershed. Conservative, dissolved constituents tend to be transported undiminished, while particulate and reactive materials may be subject to substantial processing.

Though generalized results are transferable, the variability found indicates that specific numerical results are unique to an area.

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GENESEE RIVER

PILOT WATERSHED STUDY

SUMMARY PILOT WATERSHED REPORT

Submitted to

International Joint Commission

Internation Reference Group on Pollution from Land Use Activities

by

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2. DISCLAIMER

This study was carried out as part of the efforts of the Pollution from Land Use Activities Reference Group, International Joint Commission.

Findings are those of the authors and do not necessarily reflect the views of the Reference Group or its recommendations to the International Joint Commission.

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5. CONTENTS

		Page
1.	Title Page	i
2.	Disclaimer	ii
3.	Cooperating Agencies and Funding	iii
4.	Acknowledgements	iv
5.	Table of Contents	v
6.	List of Tables	vii
7.	List of Figures	viii
8.	Summary	1
9.	Introduction	2
9.1.1	Study Objectives	2
9.1.2	The Genesee River Watershed	2
9.2	Study Approach	4
9.3	Data Collection Methods	8
9.4	Key Parameters and Analytical Procedures	10
10.	Tabulated Results of Data Collected	12
10.1	Land Use	12
10.2	Estimation of Study Year Loadings of Phosphorus, Sediment and Chloride	12
10.3	Inventory of Point Discharges in the Genesee River Basin	25
10.3.1	Upstream Point Source Discharges	25
10.3.2	Rochester Point Source Discharges	25
10.4	Distribution of Net Unit Loads	29
10.5	Delivery Ratio	29
10.5.1	Suspended Sediment	33
10.5.2	Phosphorus	37
10.5.3	Chloride	40
10.6	Land Use, Soils, Geology and Water Quality	40
10.7	Special Studies	48
10.7.1	Water Quality Studies at Mill Creek, New York	48
10.7.1.1	Sampling Interval Studies at Mill Creek, New York	48
10.7.1.2	Inventory of Forms of Nutrients Stored in a Watershed	49
10.7.2	Nitrogen and Phosphorus Losses in Drainage Water from Organic Soils	49
10.7.3	Nutrients and Heavy Metals in Genesee River Sediments	57
10.7.4	Streamflow and Sediment Transport in the Genesee River Basin, New York	60
10.7.5	A Synoptic Survey of Base Flow Water Chemistry in the Genesee River Watershed	61

		Page
10.7.6	Geochemistry of Oxide Precipitation in the Genesee River Watershed	62
10.7.7	Point Source Phosphorus Influence and Cycling in Streams	66
10.7.8	Stream Bank Erosion Study	67
10.7.9	Evaluation of the Bogardi T-3 Bedload Sampler	67
10.7.10	Surficial Geology of the Genesee Basin	67
11. Data Interpretations and Conclusions		69
11.1	Causes and Sources of Pollutant Contribution	69
11.2	Extent of Pollutant Contributions in Unit Area Loadings and Seasonal Variations	69
11.3	Relative Significance of Sources Within the Watershed	69
11.4	Transmission of Pollution	69
11.5	Data Transferability	70
12. References		71

6. TABLES

No.		Page
1.	Genesee River Watershed Study - Special Studies	9
2.	Land Use Groupings	11
3.	Genesee River Basin Land Use Summary	
a.	Genesee River Main Stem	13
b.	Canaseraga Creek	14
c.	Oatka Creek	15
4.	Study Year 1975: Loadings of Total Phosphorus, Suspended Solids and Chloride	19
5.	Study Year 1976: Loadings of Total Phosphorus, Suspended Solids and Chloride	20
6.	Ratio of Winter to Summer Loads and Stream Flows Study Year 1975	24
7.	Inventory of Point Discharges	
a.	Municipal	27
b.	Industrial	28
8.	Suspended Solids and Phosphorus Load Estimates	36
9.	Chloride Mass Balance	42
10.	Geology and Soil Indices	40
11.	Statistics for Phosphorus Analyses for Several Sediment Types Collected in the Genesee River Watershed	58
12.	Statistics for Total Analyses of Bottom Sediments Collected in the Genesee River Watershed	59
13.	Mean Metal Concentrations in Genesee River Watershed Sediment, Average Shale Composition and Typical Lake Sediments Rich in Ca-Mg Carbonates	59

7. FIGURES

No.		Page
1.	Genesee River Basin Map	3
2.	Genesee River Watershed-Bedrock Geology	5
3.	Genesee River Watershed-Parent Soil Material	6
4.	Genesee River Watershed-Land Use	7
5.	Mean Square Error vs. Cutoff Percentile for Total Phosphorus, Chloride and Suspended Solids - Genesee River at Avon	16
6.	Mean Square Error vs. Cutoff Percentile for Total Phosphorus, Chloride and Suspended Solids - Canaseraga Creek at Shakers Crossing	17
7.	Mean Square Error vs. Cutoff Percentile for Total Phosphorus, Chloride and Suspended Solids - Genesee River at Portageville	18
8.	Total Phosphorus-Gross Unit Loads	21
9.	Suspended Solids-Gross Unit Loads	22
10.	Chloride-Gross Unit Loads	23
11.	Genesee River Basin - Point Discharges	26
12.	Study Year 1975-Net Total Phosphorus Unit Loads	30
13.	Study Year 1975-Net Chloride Unit Loads	31
14.	Study Year 1975-Net Suspended Solids Unit Loads	32
15.	Unit Load Calculation Flow Chart	34
16.	Estimated Suspended Solids Unit Load	35
17.	Estimated Particulate Phosphorus Unit Load	38
18.	Estimated Soluble Phosphorus Unit Load	39
19.	Estimated Chloride Unit Load	41
20.	Chloride Concentration vs. Land Use	44
21.	Chloride Concentration vs. Geology Index and Soil Drainage Index	44
22.	Total Soluble Phosphorus vs. Land Use	45
23.	Total Soluble Phosphorus log Coefficient of Variation vs. Geology Index and Soil pH Index	45
24.	Soil pH Index vs. Land Use	46
25.	Geology Index vs. Land Use	46
26.	Slope Index vs. Land Use	47
27.	Soil Drainage Index vs. Land Use	47
28.	Mill Creek - Stream Discharge vs. Sampling Interval	50
29.	Mill Creek - Chloride Concentration vs. Sampling Interval	51
30.	Mill Creek - Chloride Load vs. Sampling Interval	51
31.	Mill Creek - Particulate Phosphorus Concentration vs. Sampling Interval	52
32.	Mill Creek - Particulate Phosphorus Load vs. Sampling Interval	52
33.	Mill Creek - Soluble Phosphorus Concentration vs. Sampling Interval	53
34.	Mill Creek - Soluble Phosphorus Load vs. Sampling Interval	53

No.		Page
35.	Mill Creek - Suspended Solids Concentration vs. Sampling Interval	54
36.	Mill Creek - Suspended Solids Load vs. Sampling Interval	54
37.	Mill Creek - Annual Phosphorus Budget	55
38.	Mill Creek - Monthly Phosphorus Loss	56
39.	Synoptic Survey - Areal Runoff	63
40.	Synoptic Survey - Soluble Phosphorus Concentration	63
41.	Synoptic Survey - Chloride Concentration	64
42.	Synoptic Survey - Calcium Concentration	64
43.	Synoptic Survey - Calcium, Chloride and Soluble Phosphorus vs. Geology	65

8. SUMMARY

The Genesee River was monitored for stream flow and a variety of water water quality parameters under a program sponsored by the Internation Joint Commission, Pollution from Land Use Activities Reference Group, Task C, Pilot Watersheds Study. An integrated sampling program was operated from March 1975 through June 1977. Twenty-eight stations covered the spectrum of land use, soil type and geologic development found in the watershed. Pollutants studied in detail were total phosphorus, suspended solids and chloride.

Results of the study suggest that water quality is not entirely dependent on land use; soil type, geology and geomorphology also have strong influence on the amounts and forms of various pollutants transported by surface waters. The intensely farmed areas in the central and northern portion of the watershed lie on calcareous soils. These areas contribute higher unit loads of phosphorus, chloride and suspended solids than does the remainder of the watershed. Areas of cultivated muck land produce elevated phosphorus unit loads, and excessive chloride production is identified with those regions having extensive salt mining operations.

Variations in river loading indicate that urban land is relatively more productive than agriculture for the parameters studied. Forested land is the least productive. A portion of urban impact is associated with point source discharges particularly with respect to chloride and phosphorus. Suspended solids, as an urban point source, have little impact. Large chloride point sources are storm water runoff and phosphorus is contributed from municipal wastewater.

Transport of the several pollutants is variable within reaches and over the watershed. Conservative, dissolved constituents tend to be transported undiminished, while particulate and reactive materials may be subject to substantial processing. The nature of the system, however, makes it difficult to identify specific delivery ratios, though there is a displacement in time of the transport of particulate material. Depending on flow and specific reach, the displacement varies in time from days to months.

Generalized results are transferable, but the variability found indicates that specific numerical results are unique to an area. Unless a watershed with similar land use practices, soil types and geology can be identified, the results cannot be transferred. This limits extrapolation to very small areas where specific numerical results can be transferred or very large areas where generalized qualitative results are sufficient.

9. INTRODUCTION

9.1.1 Study Objectives

Concern for the deterioration of Great Lakes water quality has prompted the Governments of the United States and Canada to conduct studies of the impact of land use (i.e. man's activities) on the water quality of the Great Lakes. By the authority of the Great Lakes Water Quality Agreement of April 15, 1972, the International Joint Commission (IJC) authorized such studies and development of recommendations for remedial measures to maintain or improve Great Lakes water quality. Through the Great Lakes Water Quality Board, the IJC established the International Reference Group on Great Lakes Pollution from Land Use Activities (Pollution from Land Use Activities Reference Group - PLUARG) to carry out such studies.

PLUARG developed a study program (IJC, 1974) which consisted of four major tasks. Task A was devoted to the collection and assessment of management and research information and, in its later stages, to the critical analysis of implications of potential recommendations. Task B was responsible for the preparation of a land use inventory (largely from existing data) and the analysis of trends in land use patterns and practices. Task C was to carry out detailed surveys of selected watersheds to determine the sources of pollutants, their relative significance and the assessment of the degree of transmission of pollutants to boundary waters. Task D was devoted to obtaining supplementary information on the impacts of materials on the boundary waters, their effect on water quality and their significance in these waters in the future and under alternative management schemes. The PLUARG Study Plan was approved by the Great Lakes Water Quality Board in March 1974 and the IJC in April 1974.

The Task C portion of the Detailed Study Plan included intense investigations of six watersheds in Canada and the United States which represent the full range of urban and rural land uses found in the Great Lakes Basin. A Technical Committee and Task C Subgroup have developed and conducted the pilot watershed studies. The Genesee River Watershed was selected as a pilot study area to quantitatively determine the effects of various land use activities, soils, geomorphology and geology on surface water quality. Also, the rates and nature of transmission of selected pollutants, particularly suspended sediment, phosphorus and chlorides to Lake Ontario were assessed.

9.1.2 The Genesee River Watershed

The Genesee River Watershed is a 636,400 ha drainage area in central New York and north central Pennsylvania (Figure 1). The watershed is roughly rectangular in shape and running south to north, has 247 km of mainstream river reach. At Lake Ontario, the Genesee has had a long-term mean flow of 77 m^3/sec. The climate of the basin is humid, having cold winters and mild summers, with mean annual temperatures of 13°C in the lower basin and 7°C in the upland areas. Mean annual precipitation for the watershed is 86.4 cm, ranging from 106.7 cm in the upper basin to 71.1 cm in the lowlands. Local cloudburst storms are common throughout the basin as are summertime rainfall deficiencies (U.S. Army Corps of Engineers, 1967).

Figure 1. Genesee River Basin Map

The modern Genesee drainage system is the product of extensive working and reworking by the glacial succession during the Pleistocene Period starting with the Wisconsinan Glaciation that formed the Olean terminal Moraine band across southern New York and northern Pennsylvania. Subsequent retreats and readvances deposited the Valley Heads Moraine forming the terminus for the glacial Finger Lakes of central New York. These deposits left characteristic till in many of the steep, upland streambeds. Final glacial activity in the north diverted the Genesee to its present discharge into Lake Ontario; a consequence of the deposit of the Albion Moraine and the drumlin fields to the south and east of Rochester.

Soils in the basin were created through reworking of the land surface by glaciation. This process tended to grind and transport the characteristic bedrock materials southward, distorting in the soils the more clearly defined breakpoints of the bedrock. The transport moved calcareous material to the south, producing a more extensive alkaline soil environment than the composition of the parent material would suggest.

The Genesee River Basin is developed on three major terraces that are separated by northward facing escarpments. The Allegheny Plateau extends from the headwaters in Pennsylvania to the Portage Escarpment which runs approximately east to west, dipping southward east of Mt. Morris. Bedrock assemblages of the Allegheny Plateau area are interbedded sandstone and shale (Figure 2), while soils are primarily glacial tills and outwash (Figure 3). Upland areas (above 500 m) are classified as frigid soils made up of mixtures of siltstone, shale and sandstone tending toward an acid reaction pH. These soils have poor to moderately good drainage capabilities. Major tributaries of the Genesee are bedded on more alkaline/calcareous lake and marine sediments. Land use developments in the Allegheny Plateau are dominated by forest with some agricultural activity (Figure 4). To the south are areas of oil and gas extraction. There is limited population development in the southern portion of the watershed.

North of the Portage Escarpment lie three narrow plains separated by narrow scarps. The Erie Plain of calcareous shales is terminated by the limestone Onondaga Escarpment as the bedrock moves into the Huron Plain which is supported on alternating dolostone and calcareous shale formations. Soils of these two plains are predominantly glacial tills of limestone with shale and sandstones and have moderately good drainage. Lake and marine sediments form the major stream beds. All the soils in the Erie and Huron Plains tend toward alkaline reaction pH. Forest in the Allegheny Plateau give way to extensive agricultural development in the central and north central Genesee Basin. Population centers tend to be larger and more frequent toward the north.

The Niagara Excarpment, running through the city of Rochester, delineates the narrow Ontario Lake Plain. Imperfectly and poorly drained lacustrine silt and clay deposits make up the mildly alkaline soils of the plain. The portion of the watershed developed in the Lake Plain is taken up by the City of Rochester, the major urban center of the Genesee Basin.

9.2 Study Approach

The watershed field sampling was designed to cover not only the land use variations of the Genesee country, but to also consider the variations in geologic and soil system development (Figures 2-4). A total of 28 routine

Figure 2. Genesee River Watershed-Bedrock Geology

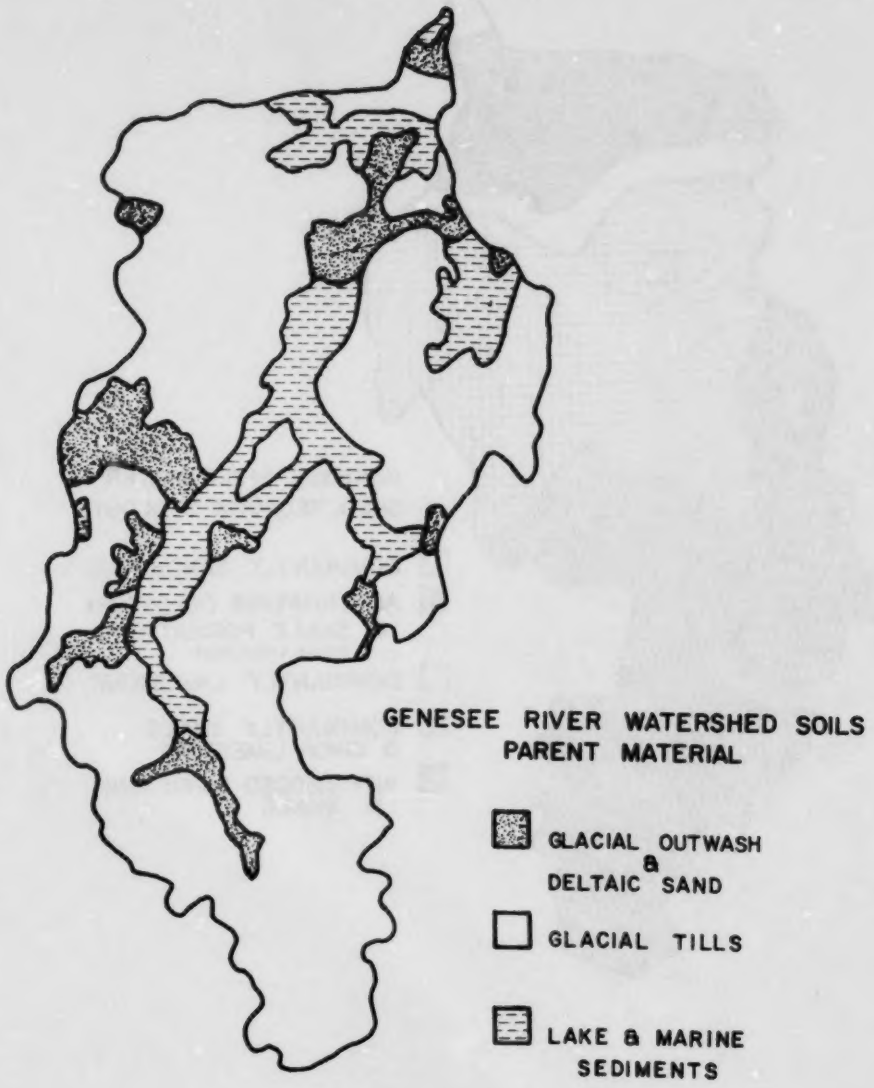

Figure 3. Genesee River Watershed-Parent Soil Material

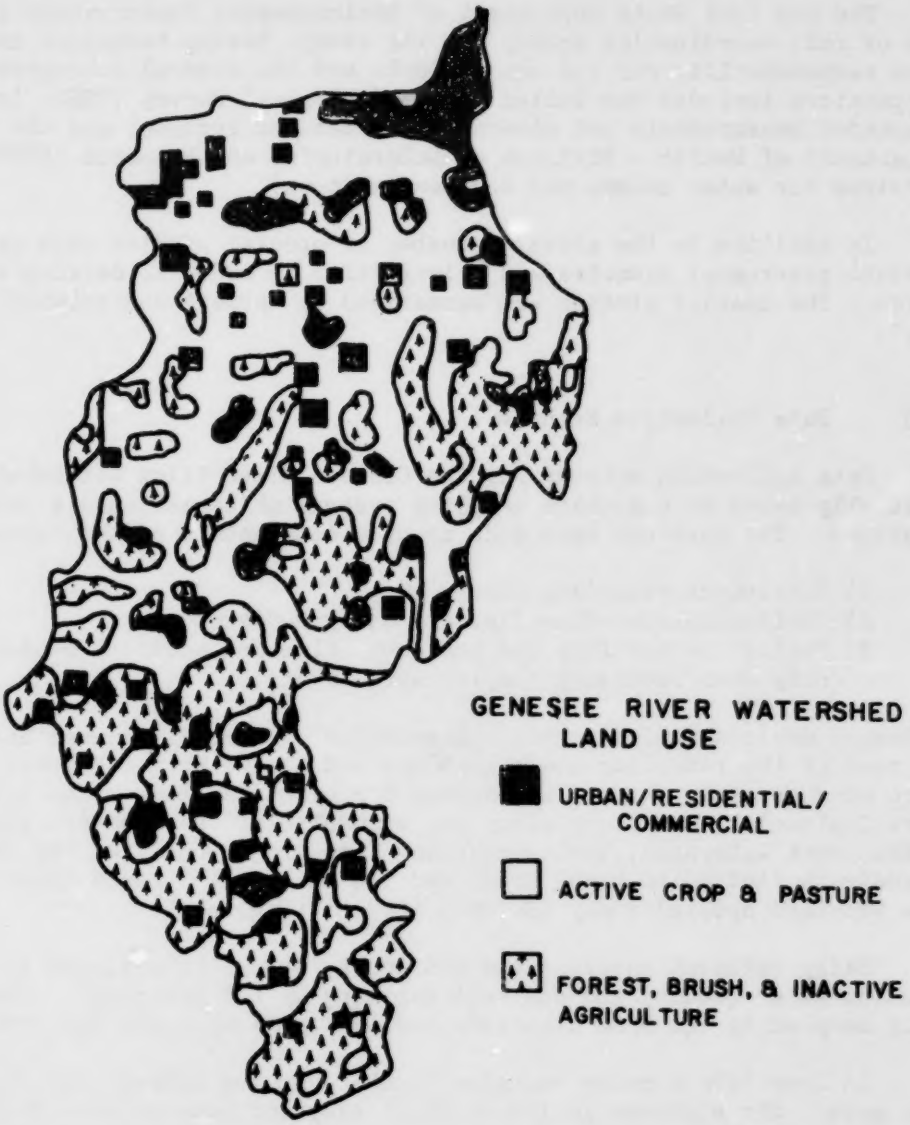

Figure 4. Genesee River Watershed-Land Use

sampling stations for streamflow, suspended sediments and water chemistry were established along the main stem of the Genesee and three of its major tributaries; Black Creek, Canaseraga Creek and Oatka Creek (Figure 1). Figure 1 also shows sample sites associated with a synoptic survey of the watershed (Section 10.7.5).

The New York State Department of Environmental Conservation (NYS DEC) was the overall coordinating agency for the study, having technical and administrative responsibility for its own projects and the several subcontractors. Major cooperators included the United States Geological Survey (USGS) (streamflow and suspended measurements and mineralogical data collection) and the New York State Department of Health - Division of Laboratories and Research (NYSDH) (analytical services for water column and sediment systems).

In addition to the above, a number of special studies were assigned to various government agencies and universities in order to develop specific information. The special studies are summarized in Table 1 and detailed in Section 10.7.

9.3 Data Collection Methods

Data collection methods for the Genesee River Pilot Watershed Study were initially based on a routine sampling program which included a total of 28 stations. The stations were made up of a combination of the following:

1) Continuous recording flow
2) Continuous recording flow and daily sediment
3) Partial record flow and sediment (Flow and sediment measured only when chemistry samples were taken)

Telemark devices (which permit transmission of remotely sensed data by phone) at most of the recording stage stations and at two weighing precipitation gages were used as early warning mechanisms for event sampling. The established network included six stations along the main stem of the Genesee, plus seven in the Oatka Creek watershed, twelve covering Canaserage Creek and its tributaries, one downstream station on Black Creek and two on Little Conesus Creek in support of the muckland special study (Section 10.7.2) (Figure 1).

Daily sediment sampling was handled by observers employed by the USGS and routine water quality and sediment sampling by DEC personnel. Events were manually sampled by the USGS observers and DEC sampling teams for most of the study.

In June 1976 a major revision in the sampling network and sampling strategy was made. Six stations in the original sampling network were dropped; the Black Creek site, one intermediate site each on Oatka and Canaseraga Creeks, the muck area station on Bradner Creek and the two muck sites on Little Conesus Creek. The first four sites were dropped because of poor flow record generation and the two Conesus sites because the muckland special study was completed.

Changes in the sampling strategy included extension of the routine sampling interval to one month and installation of six automatic samplers. Extension of the sampling frequency was made to promote response to events both in manual sampling and in servicing the automatic sampling equipment. Additionally, three sites (the downstream sites on Oatka and Canaseraga Creeks and the Genesee site

Table 1. GENESEE RIVER WATERSHED STUDY - SPECIAL STUDIES

Organization	Study
New York State Department of Environmental Conservation	a) Mill Creek Optimum Sampling Strategy Evaluation b) Genesee Synoptic Survey
New York State Department of Health, Division of Laboratories and Research	Suspended and bed sediment chemistry-nutrients and metals
New York State Department of Education, Geological Survey	Mineralogical analysis and geochemistry of sediment oxide precipitates
United States Geological Survey	Suspended sediment sources and transport in relation to basin parameters
United States Department of Agriculture, Soil Conservation Service	a) Detailed soils mapping and analysis b) Stream Bank Erosion Study
Rensselaer Polytechnic Institute, Troy, NY	a) Evaluation of a differential pressure bedload sampling device b) Inventory and estimation of nutrients and nutrient fluxes in a small agricultural watershed
Cornell University Ithaca, NY	a) Estimation of nutrient loss rates from cultivated organic soils b) Point source phosphorus influence and cycling in streams

below Mt. Morris) were sampled daily by the respective USGS observers for water chemistry. These modifications of the sampling program continued until the end of the field work in June 1977.

Land use data related to the Genesee watershed is taken from the Land Use and Natural Resources (LUNR) Inventory prepared by Cornell University (Hardy and Shelton, 1970).

Development of the inventory is based on 1967-1968 aerial photography and field checks between 1967 and 1969. Land use is divided into 11 major groups which are subdivided into 51 land use categories each having a mimimum map area of one acre (2.47 ha). From this data base, mylar overlays based on the 24,000 scale USGS quadrangles were developed. Coding of the data for analytical purposes was based on the Universal Transverse Mercator (UTM) grid producing cells of 1 square kilometer. The two watersheds under intensive study and the synoptic survey sub-basins were coded at a resolution of one-quarter UTM Cells. Land use classifications utilized are summarized in Table 2 and are those identified for general investigation by PLUARG Task B (IJC, 1977a).

Soils and bedrock geology data are also available, but are not reported in detail in this report.

9.4 Key Parameters and Analytical Procedures

Water column chemical analysis included particulate and soluble phosphorus, nitrogen and carbon species, chloride, sulfate, silica, iron, calcium, magnesium, potassium and sodium. Field measurements included pH, alkalinity, hardness, air and water temperature, dissolved oxygen and stream flow. Samples collected by USGS observers and automatic equipment were analyzed for total phosphorus, nitrogen, carbon, chloride, silica, sulfate, iron, calcium, magnesium, manganese and sodium. Based on PLUARG needs, this report will discuss only phosphorus, suspended sediments and chloride.

Sediment sampling included suspended and bed material. Analysis of the various sediment fractions included species of phosphorus, nitrogen and carbon plus aluminum, copper, chromium, iron, manganese, nickel, lead and zinc. Presentation of sediment chemical analysis in this report will include phosphorus and these metals. Analytical procedures used in water column analysis are either Environmental Protection Agency (EPA, 1974) or "Standard Methods" (WPCA, 1971) procedures. Precision, significance thresholds and detection limits are as reported by Krishnamurty and Reddy (1975). Analytical methods used in special studies are referenced by individual investigators in their detailed study reports.

Table 2. LAND USE GROUPINGS

PLUARG - Task B Designation	LUNR Classification
Residential	Residential - high, medium & low density Strip Development Rural residential, low density, hamlet, farm labor, estate
Commercial - Industrial	Transportation and utility corridors Airports Commercial business and strip development Industrial - light and heavy
Cropland	Active Cropland High intensity agriculture Horticulture Orchards
Pasture	Permanent/unrotated pasture
Forest	Natural stands Stocked stands Brush Inactive agriculture
Outdoor Recreation	Commercial recreation Outdoor recreation
Wetlands	Wooded wetlands Marsh
Inland Waters	Natural and artificial ponds Streams and rivers
Miscellaneous	Extractive Industries Public lands

10. TABULATED RESULTS OF DATA COLLECTED

10.1 Land Use

Land use activities are described in Section 9.1.2 as they generally relate to geologic and soils development in the Genesee Watershed. Table 3 (a, b, c) presents the detailed breakdown of land use activities for the basin by subwatersheds as they were sampled during the study.

10.2 Estimation of Study Year Loadings of Phosphorus, Sediment and Chloride

Annual loadings of total phosphorus, suspended sediment and chloride were estimated for two study years (1975 - June 2, 1975 to May 31, 1976 and 1976 - June 1, 1976 to May 31, 1977) for six main stem stations and 19 tributary stations in the Genesee Watershed. The method of calculation utilized Beale's ratio estimator as modified by Clark (IJC, 1977b). The computer program was obtained from John Clark and used without modification. The chemical data sets representing samples collected at biweekly or monthly intervals were stratified at the 85th stream discharge percentile. For a first approximation, this cutoff point seems to minimize the mean square error (MSE) of the estimate. Figures 5-7 compare MSE and cutoff percentile for three selected sampling stations. The curves can hardly be described as having a true minimum, but an 85 percent cutoff seems to generally yield the lowest MSE for the three parameters studied.

Tables 4 and 5 show the calculated phosphorus, sediment and chloride annual loads, MSE and the percent each load is of the loading at the mouth of the Genesee River for study years 1975 and 1976, respectively. Figures 8-10 show the unit loadings (kg/ha/yr) upstream of each sampling point for phosphorus, sediment and chloride for the two years. This diagram is not drawn to scale and represents the watershed only in a schematic fashion. Table 6 shows the ratio of winter to summer loadings of the three parameters and stream discharge for study year 1975. For purposes of this table, summer is defined as May through October.

Estimates of material dredged from Rochester Harbor by the U.S. Army Corps of Engineers (Greener, 1977) are 174,200 tonnes and 124,000 tonnes for the two study years. These estimates represent 17.2 percent and 22.8 percent of the total sediment load delivered at the mouth of the river each year.

The influence of runoff events on water quality in the Genesee Watershed is significant. At the seven sites where adequate stream discharge and suspended sediment records exist, approximately two-thirds of the water and over ninety percent of the suspended sediment are discharged during runoff events. In contrast, runoff events occur for only one day out of three.

Table 3a. GENESEE RIVER BASIN LAND USE SUMMARY

Genesee River Main Stem

Watershed*	Land Use									
	Cropland	Pasture	Residential	Commercial-Industrial	Forest	Outdoor Recreation	Wetlands	Inland Water	Misc.	Tot. Area
Wellsville	32.3**	3.6	2.3	.3	49.6		4.9	.3	6.7	100.0
	24,200	2,700	1,720	220	37,150		3,670	220	5,020	74,900
Transit Bridge	28.5	3.6	4.0	.5	53.8	.2	2.4	.3	6.7	100.0
	42,580	5,380	5,980	750	80,380	300	3,580	450	10,000	149,400
Portageville	30.3	4.1	3.6	.3	54.9	.2	2.4	.2	4.0	100.0
	77,000	10,420	9,140	760	139,500	510	6,100	510	10,160	254,100
Mt. Morris	35.3	4.8	3.6	.8	47.5	2.1	2.6	.3	3.0	100.0
	129,600	17,620	13,200	2,940	174,300	7,700	9,540	1,100	11,000	367,000
Avon	39.9	5.1	4.2	.9	42.1	1.9	2.6	.6	2.7	100.0
	172,300	22,000	18,100	3,900	181,800	8,200	11,200	2,600	11,700	431,800
Rochester (RG & E)	44.7	4.2	6.0	2.6	33.8	1.5	4.1	.7	2.4	100.0
	284,500	26,700	38,200	16,500	215,100	9,550	26,100	4,450	15,300	636,400

* Key to subwatershed map - Figure 1.

** Percent of Basin
Area - Hectares

Table 3b. GENESEE RIVER BASIN LAND USE SUMMARY

Canaseraga Creek

Watershed *	Land Use									
	Cropland	Pasture	Residential	Commercial-Industrial	Forest	Outdoor Recreation	Wetlands	Inland Water	Misc.	Tot. Area
Sugar Cr.	28.0**	3.6	.5		66.9		.5	.5		100.0
	1,390	170	30		3,320		30	30		4,970
Poags Hole	26.2	4.5	1.0	.1	64.5	.5	1.0	1.2	1.0	100.0
	6,110	1,050	230	20	15,030	120	230	280	230	23,300
Stony Br.	41.5	6.0	.5		46.0	3.5	.5	.5	1.5	100.0
	2,230	320	30		2,480	190	30	30	80	5,390
Mill Cr.	44.2	11.7	5.8	5.3	23.6		3.6	2.2	3.6	100.0
	4,110	1,090	540	490	2,200		330	210	330	9,300
Dansville-Rt. 436	32.4	6.7	2.3	1.7	51.2	1.2	1.5	1.3	1.7	100.0
	12,800	2,650	910	670	20,300	480	600	520	670	39,600
Groveland	35.1	7.6	2.8	2.3	47.2	1.1	1.3	1.1	1.5	100.0
	16,500	3,560	1,310	1,080	22,100	520	610	520	700	46,900
Bradner-Rt. 36	49.0	14.3		1.0	33.7				2.0	100.0
	940	280		20	650				40	1,930
Bradner-Pioneer Rd.	50.6	8.7	.5	1.3	36.3	.8	.5		1.3	100.0
	5,360	920	50	140	3,850	90	50		140	10,600
Keshequa-Nunda	17.2	9.4	6.6	1.3	61.3		2.5	1.3	.4	100.0
	1,450	790	550	110	5,150		210	110	30	8,400
Keshequa-Tuscarora	30.9	9.6	4.0	.8	52.3	.4	1.2	.6	.2	100.0
	4,700	1,460	610	120	7,950	60	180	90	30	15,200
Keshequa-Sonyea	34.0	9.0	3.3	.7	50.4	.3	1.0	.5	.8	100.0
	6,060	1,600	590	130	8,980	50	180	90	140	17,820
Shakers Crossing	35.6	8.4	2.9	1.8	46.6	1.0	1.5	.7	1.5	100.0
	30,700	7,240	2,500	1,540	40,200	860	1,280	600	1,280	86,200
at mouth	35.6	8.4	2.9	1.8	46.7	.9	1.5	.7	1.5	100.0
	30,800	7,260	2,500	1,560	40,300	780	1,300	600	1,300	86,400

* Key to watershed map - Figure 1.

** Percent of Basin
Area - Hectares

Table 3c. GENESEE RIVER BASIN LAND USE SUMMARY

Oatka Creek

Watershed*	Land Use									
	Cropland	Pasture	Residential	Commercial-Industrial	Forest	Outdoor Recreation	Wetlands	Inland Water	Misc.	Tot. Area
Rock Glen	52.3**	2.3	.5		42		2.9			100.0
	2,140	90	20		1,730		120			4,100
Warsaw	44.2	5.3	2.3		40.8	1.4	6.0			100.0
	4,820	580	250		4,450	150	650			10,900
Pearl Cr.	59.5	9.5			31.0					100.0
	1,680	270			870					2,820
Oatka @ Pearl Cr.	45.5	8.0	2.2		38.8	.7	4.5		.3	100.0
	9,510	1,670	460		8,110	150	940		60	20,900
Pavilion	50.7	7.8	2.1	.1	34.5	.7	3.9		.2	100.0
	14,550	2,240	600	30	9,900	200	1,120		60	28,700
Mad Cr.	79.3	.9		.9	14.2	.9		3.8		100.0
	2,080	20		20	380	20		100		2,620
Garbutt	55.3	5.8	1.9	.2	30.8	1.0	4.0	.2	.8	100.0
	29,200	3,050	1,000	100	16,300	520	2,110	100	420	52,800
at mouth	55.9	5.7	1.9	.3	30.3	.9	3.9	.2	.9	100.0
	31,100	3,190	1,060	170	16,800	500	2,170	110	500	55,600

* Key to watershed map - Figure 1.

** Percent of Basin
Area - Hectares

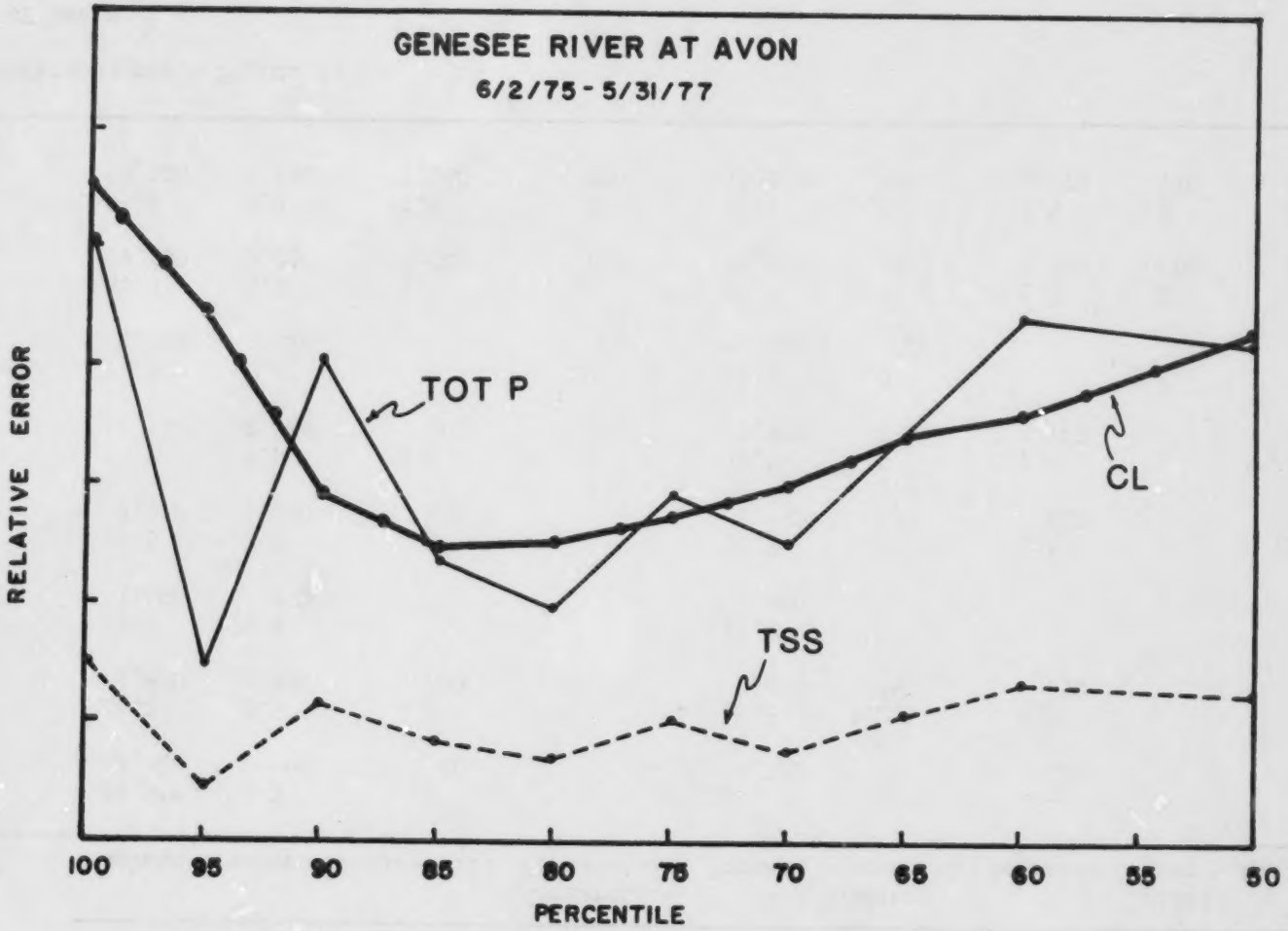

Figure 5. Mean Square Error vs. Cutoff Percentile for Total P,Cl and SS - Genesee River at Avon

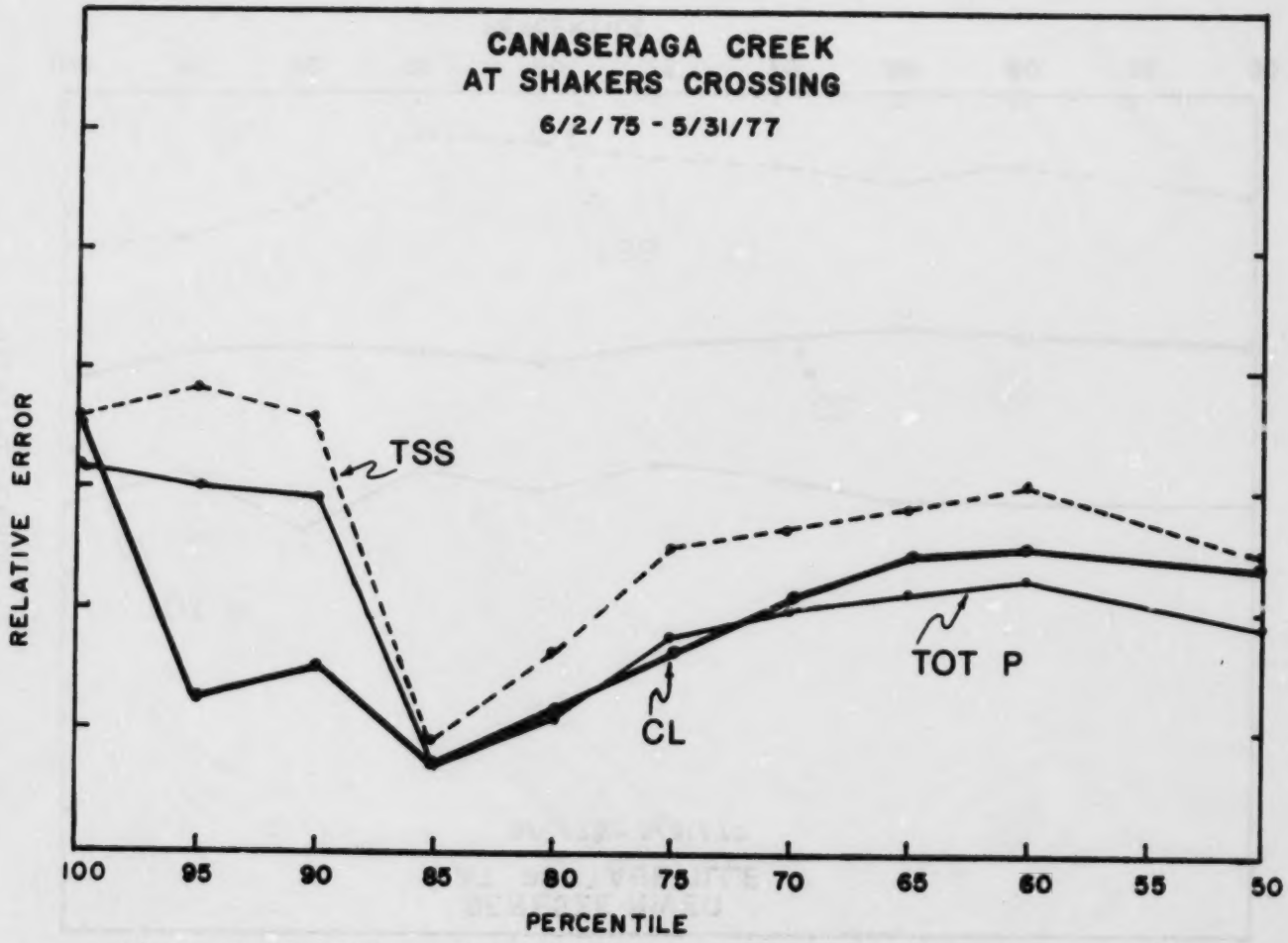

Figure 6. Mean Square Error vs. Cutoff Percentile for Total P,Cl and SS - Canaseraga Creek at Shakers Crossing

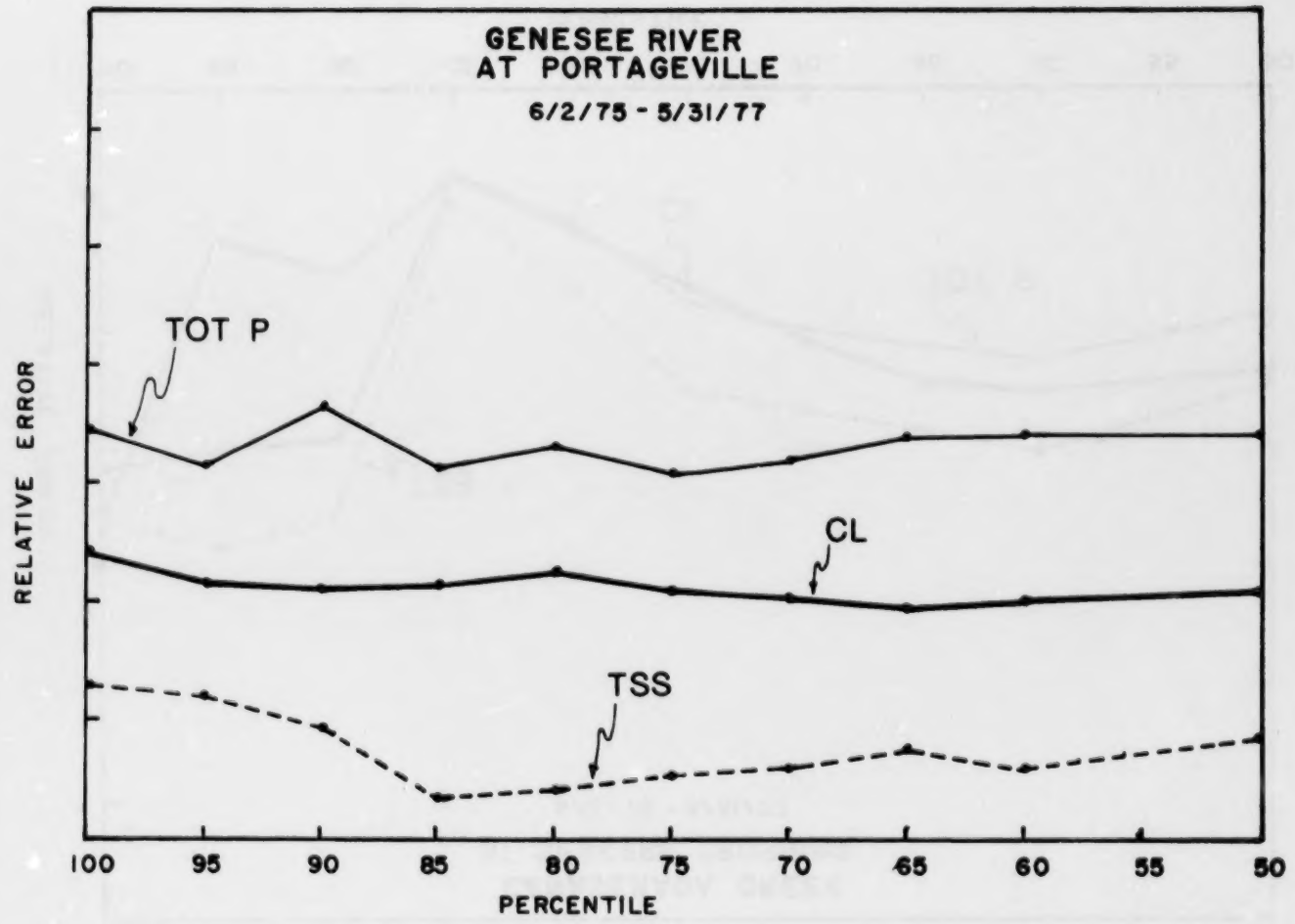

Figure 7. Mean Square Error vs. Cutoff Percentile for Total P,Cl and SS - Genesee River at Portageville

Table 4. STUDY YEAR 1975 LOADINGS OF TOTAL PHOSPHORUS, SUSPENDED SOLIDS AND CHLORIDE (tonnes/year)

STATION**	TOTAL P			TOTAL SUS SOL			CHLORIDE		
	LOAD	SMSE	% MOUTH	LOAD	SMSE	% MOUTH	LOAD	SMSE	% MOUTH
G/Rochester	813.17	104.42	100.00	1,014,350	190,926	100.00	126,812	10,741	100.00
G/Avon	441.13	59.82	54.25	640,755	113,879	63.17	71,076	6,233	56.05
G/Mt. Morris	403.39	46.45	49.61	803,865	185,911	79.25	29,110	2,221	22.96
G/Portageville	190.58	22.48	23.44	264,333	25,391	26.06	19,049	1,854	15.02
G/Transit Bridge	74.88	2.43	9.21	78,758	5,126	7.76	12,364	460	9.75
G/Wellsville	17.62	9.32	2.17	4,663	844	.46	5,090	461	4.01
Black Creek	5.45	1.10	.67	1,240	311	.12	4,991	215	3.94
O/Garbutt	15.90	3.87	1.96	5,513	1,451	.54	10,083	307	7.95
O/Pavilion	13.53	4.87	1.66	3,839	1,509	.38	5,474	426	4.32
O/Pearl Creek	8.93	.79	1.10	2,609	220	.26	3,419	125	2.70
O/Warsaw	10.21	4.45	1.26	8,667	2,658	.86	1,760	118	1.39
O/Rock Glen	1.22	.44	.15	833	319	.08	879	55	.69
Mad Creek	.33	.01	.04	58	4	.01	304	2	.24
Pearl Creek	3.08	1.48	.38	2,041	1,126	.20	392	22	.31
C/Shakers Crossing	76.63	23.01	9.42	75,217	38,408	7.42	7,827	336	6.17
C/Groveland	48.09	11.60	5.91	108,128	44,803	10.66	3,895	516	3.07
C/Rt. 436	23.01	5.91	2.83	37,616	10,658	3.71	2,553	187	2.01
C/Poags Hole	11.11	2.14	1.37	16,303	3,814	1.61	958	67	.76
C/Craig Colony	13.63	3.84	1.68	15,611	3,075	1.54	1,247	116	.98
K/Tuscarora	7.78	1.61	.96	11,303	2,559	1.11	1,089	72	.86
K/Kunda	5.66	1.31	.70	6,952	2,173	.69	601	42	.47
B/Rt. 36	1.15	.31	.14	834	265	.08	134	7	.01
Mill Creek	5.25	1.02	.65	8,253	1,300	.81	790	56	.62
Stony Brook	.55	.27	.07	981	684	.10	283	29	.22
Sugar Creek	.83	.16	.10	611	151	.06	240	21	.19

*SMSE = $\sqrt{\text{mean squared error}}$

** Key: G = Genesee River
O = Oatka Creek
C = Canaseraga Creek
K = Keshequa Creek
B = Bradner's Creek

Table 5. STUDY YEAR 1976 LOADINGS OF TOTAL PHOSPHORUS, SUSPENDED SOLIDS AND CHLORIDE (tonnes/year)

STATION †	TOTAL P LOAD	TOTAL P SMSE*	TOTAL P % MOUTH	TOTAL SUS SOL LOAD	TOTAL SUS SOL SMSE	TOTAL SUS SOL % MOUTH	CHLORIDE LOAD	CHLORIDE SMSE	CHLORIDE % MOUTH
G/Rochester	523.56	51.60	100.00	544,426	64,204	100.00	112,045	22,014	100.00
G/Avon	330.70	50.90	63.16	475,553	65,701	87.35	65,098	8,752	58.10
G/Mt. Morris	319.18	65.01	60.97	403,982	86,625	74.20	24,275	1,134	21.67
G/Portageville	126.68	3.96	24.20	154,260	2,408	28.33	12,361	702	11.03
G/Transit Bridge	34.88	.99	6.66	46,408	804	8.52	7,809	100	6.97
G/Wellsville	11.55	1.80	2.21	7,248	838	1.33	3,250	190	2.90
Black Creek**									
O/Garbutt	26.16	.43	5.00	10,051	105	1.85	6,329	181	5.65
O/Pavilion	11.50	.21	2.20	3,993	106	.73	3,499	68	3.12
O/Pearl Creek**									
O/Warsaw	3.40	.99	.65	3,679	1,681	.68	1,377	327	1.23
O/Rock Glen	1.20	.28	.23	730	224	.13	737	181	.66
Mad Creek	.43	.01	.08	83	3	.02	286	1	.26
Pearl Creek	.30	.18	.06	212	23	.04	377	126	.34
C/Shakers Crossing	17.52	1.02	3.35	32,699	1,068	6.01	5,055	154	4.51
C/Groveland	9.40	2.25	1.80	22,768	2,200	4.18	2,415	111	2.16
C/Rt. 436**									
C/Poags Hole	1.92	.09	.37	1,906	81	.35	711	26	.64
C/Craig Colony	1.70	.11	.33	980	77	.18	869	16	.78
K/Tuscarora	1.50	.16	.29	2,195	259	.40	764	14	.68
K/Nunda	.74	.06	.14	766	47	.14	418	15	.37
B/Rt. 36	.19	.09	.04	60	27	.01	90	7	.08
Mill Creek	2.86	.58	.55	3,915	684	.72	615	47	.55
Stony Brook	.58	.31	.11	761	537	.14	249	23	.22
Sugar Creek	.09	.01	.02	34	3	.01	86	5	.08

*SMSE = $\sqrt{\text{mean squared error}}$

**Not sampled in 1976

†Key: G = Genesee River
O = Oatka Creek
C = Canaseraga Creek
K = Keshequa Creek
B = Bradner's Creek

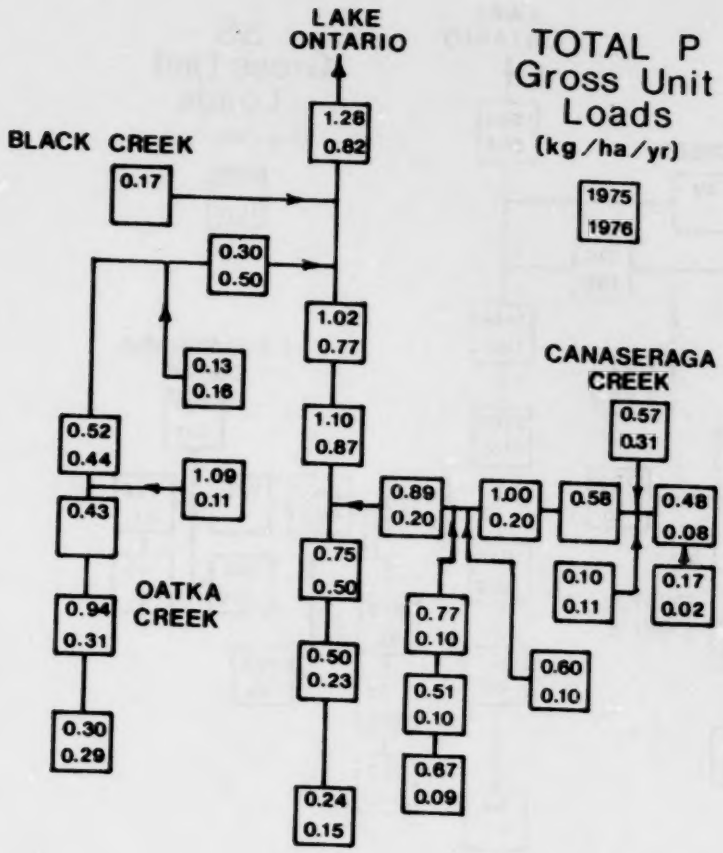

Figure 8. Total Phosphorus-Gross Unit Load

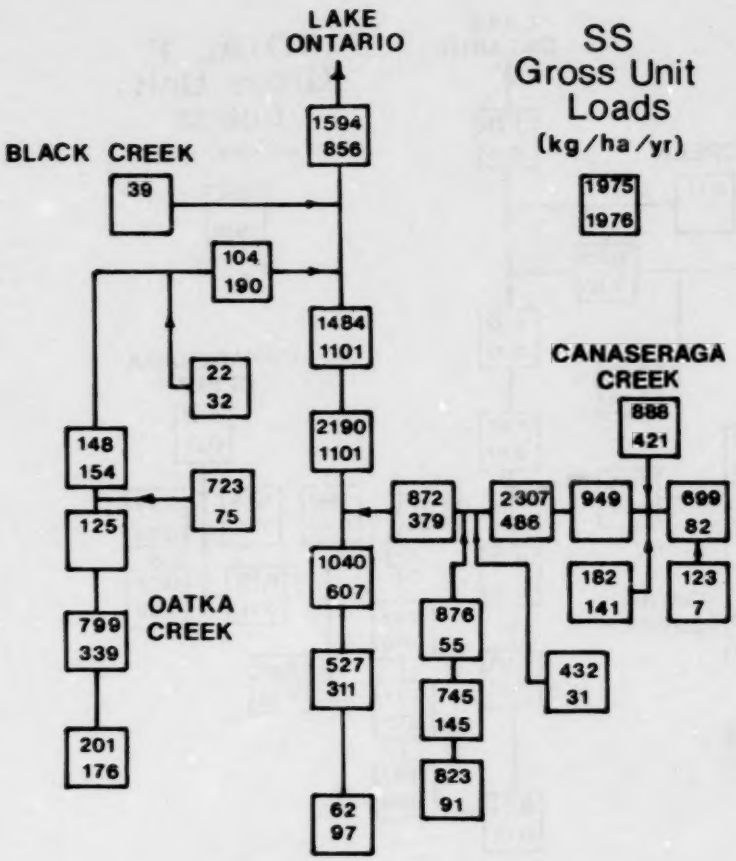

Figure 9. Suspended Solids-Gross Unit Loads

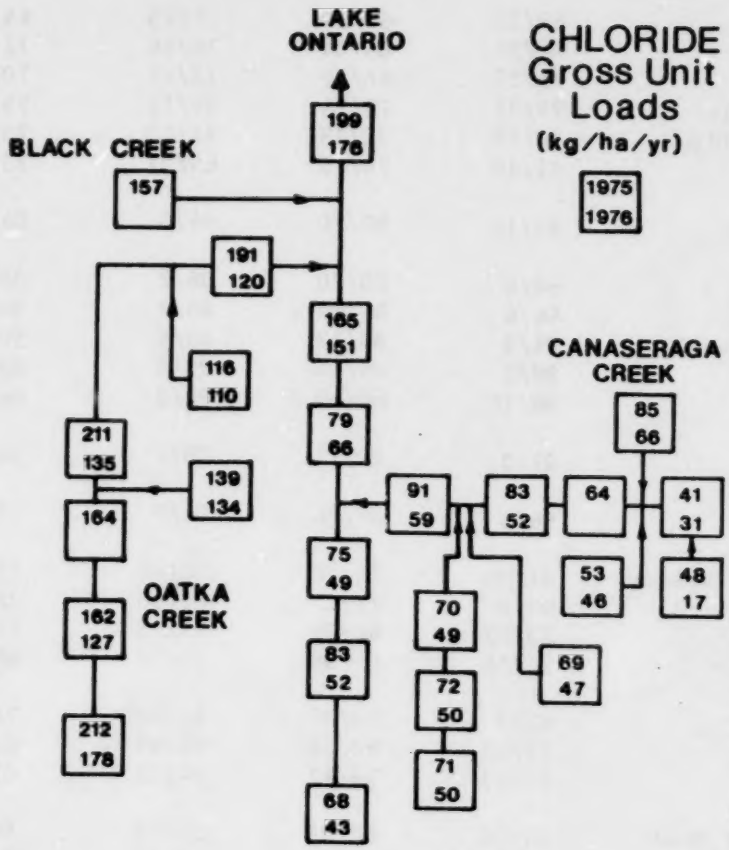

Figure 10. Chloride-Gross Unit Loads

Table 6. RATIO OF WINTER TO SUMMER LOADS AND STREAM FLOW*
STUDY YEAR 1975

Stream Station	Tot.P (%W/%S)	Cl (%W/%S)	TSS (%W/%S)	Flow (%W/%S)
Genesee River				
Rochester	68/32	66/34	77/23	65/35
Avon	76/24	66/34	76/24	72/28
Mt. Morris	78/22	68/32	73/27	70/30
Portageville	79/21	76/24	88/12	75/25
Transit Bridge	82/18	72/28	87/13	75/25
Wellsville	81/19	74/26	69/31	75/25
Black Creek				
Churchville	88/12	80/20	94/6	84/16
Oatka Creek				
Garbutt	94/6	80/20	98/2	85/15
Pavilion	96/4	86/14	98/2	91/9
at Pearl Creek	91/9	88/12	95/5	90/10
Warsaw	98/2	86/14	99/1	88/12
Rock Glen	90/10	60/40	92/8	64/36
Mad Creek	97/3	89/11	98/2	92/8
Pearl Creek	96/4	64/36	96/4	72/28
Canaseraga Creek				
Shaker's Crossing	67/33	74/26	76/24	75/25
Groveland	92/8	77/23	70/30	78/22
Dansville	73/27	68/32	77/23	71/29
Poag's Hole	26/74	66/34	30/70	64/36
Keshequa Creek				
Sonyea	93/7	73/27	88/12	78/22
Tuscarora	58/42	62/38	55/45	65/35
Nunda	57/43	58/42	64/36	61/39
Bradner's Creek				
at Pioneer Road	24/76	62/38	21/79	50/50
at Route 36	84/16	73/27	85/15	72/28
Mill Creek	16/84	47/53	14/86	48/52
Stony Brook	2/98	49/51	3/97	60/40
Sugar Creek	79/21	72/28	77/23	74/26

* - Summer is defined as May through October, Tot. P is total phosphorus, Cl is Chloride, TSS is total suspended solids and Flow is stream discharge. Units are percentage of total load or discharge.

10.3 Inventory of Point Discharges in the Genesee River Basin

There are 120 identified point source discharges in the Genesee Basin. Figure 11 and Table 7 (a & b) show the distribution and magnitude of municipal and industrial discharges throughout the watershed. The inventory of sources and loading estimates were developed from federal and state permit and monitoring data. Where data on waste flows was not identified from the permits or monitoring activities, estimates for the various parameters were derived from literature values. Combined sewer overflow (CSO) data was obtained from the Monroe County combined sewer overflow study (Anonymous, 1976).

10.3.1 Upstream Point Source Discharges

The area of the Genesee Watershed south of Rochester has 93 point source discharges. Figure 11 shows the distribution of these discharges as they correspond to the major sub-basins sampled during the field study.

Of the 93 wastewater discharges upstream of Rochester, 60 are municipal and 33 are industrial. The total municipal flow is 22 million gallons per day (MGD) and the total industrial flow is 3 MGD, though much of the industrial waste is cooling water or groundwater discharge. Phosphorus and suspended solids contributions from industrial wastewater are both less than 1 percent of the load discharged at Rochester. Industrial chloride load is a significantly higher percent because of a salt mine discharge. The salt mine was closed for part of 1975 but discharged 17,000 tonnes of chloride or 13 percent of the total chloride load that year. At full operation (1976) the chloride load was 43,000 tonnes or 38 percent of the total river load. Municipal wastewater contributes less than 1 percent of the suspended solids and chloride, and 8 percent of the phosphorus load as measured at Rochester.

10.3.2 Rochester Point Source Discharges

Within the Rochester city limits and upstream of the Rochester sample station, there are twenty-seven point source discharges. Ten point sources are located on the New York State Barge Canal, including nine oil terminal yard drains (storm drains with oil separators) and one cooling water discharge.

There are ten combined sewer overflow (CSO) points within the City. The CSO's flow during rainstorms, resulting in a mean rate of four to five MGD. Five industrial discharges have a total flow of 100 MGD, 98 of which is power plant cooling water.

Additionally, two municipal wastewater treatment plants discharge effluent to the river in this reach. Combined flow equals 32 MGD.

The twenty-seven point source discharges along the study reach in the City of Rochester have a total flow of 137 MGD. The total loads to the Genesee River are 22 percent of the phosphorus, less than 1 percent of the suspended solids and 15 percent of the chloride load. Road salting activities account for nearly all the chloride point source loads within the City.

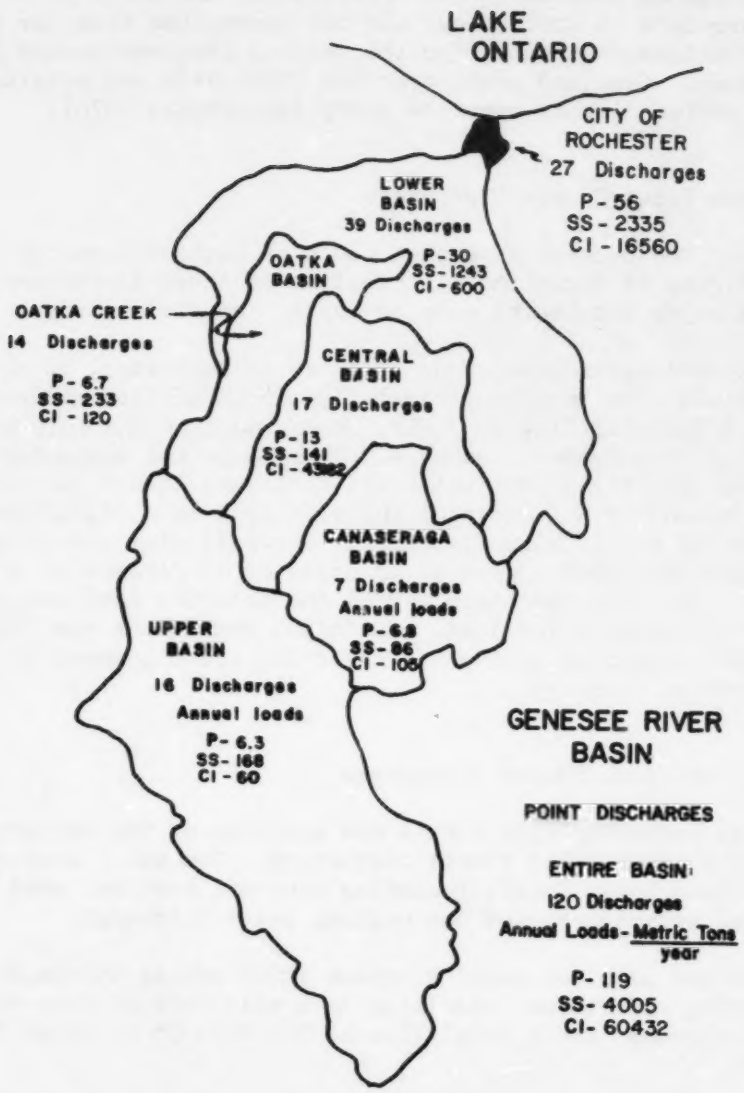

Figure 11. Genesee River Basin - Point Discharges

Table 7a. Genesee River Watershed

Inventory of Point Discharges

Municipal

Size*	Number	Discharge*	Suspended Solids**	Phosphorus**	Chloride**
Upper Basin					
< 0.01	7	.2	21.1	1.6	9.4
0.01-0.1	1	.1	4.8	.7	4.0
0.1-1.0	0	-	-	-	-
> 1.0	1	1.0	119.5	4.0	46.9
Sub-total	9	1.3	145.4	6.3	60.3
Central Basin					
< 0.01	3	< .01	< .1	< .1	.4
0.01-0.1	3	.2	21.6	1.0	6.8
0.1-1.0	4	2.0	84.2	11.0	88.7
> 1.0	0	-	-	-	-
Sub-total	10	2.2	105.8	12.0	95.9
Canaseraga Creek					
< 0.01	0	-	-	-	-
0.01-0.1	0	-	-	-	-
0.1-1.0	4	1.3	58.1	3.3	57.2
> 1.0	1	1.1	28.0	3.5	47.4
Sub-total	5	2.4	86.1	6.8	104.6
Oatka Creek					
< 0.01	3	< .01	.5	.1	.6
0.01-0.1	2	.1	.6	.3	2.4
0.1-1.0	2	1.5	120.2	5.0	67.9
> 1.0	1	1.1	72.7	1.3	49.2
Sub-total	8	2.7	194.0	6.7	120.1
Lower Basin					
< 0.01	13	.1	20.3	.9	6.5
0.01-0.1	8	.2	25.6	2.0	10.9
0.1-1.0	6	1.6	56.5	6.3	73.3
> 1.0	1	11.4	1049.3	20.7	509.4
Sub-total	28	13.3	1151.7	29.9	600.1
City of Rochester					
< 0.01	0	-	-	-	-
0.01-0.1	1	.07	7.0	.2	225.1
0.1-1.0	9	4.4	405.0	17.9	11297.9†
> 1.0	2	32.0	1309.1	37.2	4837.1
Sub-total	12	36.5	1721.1	55.3	16360.1
GENESEE RIVER BASIN					
< 0.01	19	.04	2.3	.4	1.7
0.01-0.1	19	.65	64.9	4.4	251.0
0.1-1.0	28	11.1	758.2	45.5	11598.4
> 1.0	6	46.6	2578.6	66.7	5490.0
TOTAL	72	58.4	3404.0	117.0	17341.1

* flow in million gallons per day (MGD). 1 MGD = 0.044 m^3/sec.

** tonnes/year.

† the large chloride load is primarily due to street salting.

Note: Totals may not add up exactly due to rounding errors.

Table 7b. Genesee River Watershed

Inventory of Point Discharges

Industrial

Size*	Number	Discharge*	Suspended Solids**	Phosphorus**	Chloride**
Upper Basin					
< 0.01	5	< .01	4.3	-	-
0.01-0.1	1	.01	.2	-	-
0.1-1.0	1	.2	18.1	-	-
> 1.0	0	-	-	-	-
Sub-total	7	.2	22.6	-	-
Central Basin					
< 0.01	3	< .01	.1	-	-
0.01-0.1	1	.01	< .1	< .1	.1
0.1-1.0	3	.7	35.5	1.1	43091.4†
> 1.0	0	-	-	-	-
Sub-total	7	.7	35.6	1.1	43091.4
Canaseraga Creek					
< 0.01	0	-	-	-	-
0.01-0.1	1	.01	< .1	< .1	< .1
0.1-1.0	1	.2	< .1	< .1	< .1
> 1.0	0	-	-	-	-
Sub-total	2	.2	< .1	< .1	< .1
Oatka Creek					
< 0.01	3	.01	.8	< .1	< .1
0.01-0.1	3	.1	38.0	< .1	< .1
0.1-1.0	0	-	-	-	-
> 1.0	0	-	-	-	-
Sub-total	6	.1	38.8	< .1	< .1
Lower Basin					
< 0.01	5	.01	87.9	-	-
0.01-0.1	3	.1	1.3	< .1	< .1
0.1-1.0	3	1.0	1.5	< .1	< .1
> 1.0	0	-	-	-	-
Sub-total	11	1.1	90.7	< .1	< .1
City of Rochester					
< 0.01	10	< .01	< .1	< .1	< .1
0.01-0.1	1	.01	< .1	< .1	< .1
0.1-1.0	1	.1	< .1	< .1	< .1
> 1.0	3	100.2	413.5	1.1	< .1
Sub-total	15	100.4	413.5	1.1	< .1
GENESEE RIVER BASIN					
< 0.01	24	.03	5.3	< .1	< .1
0.01-0.1	12	.25	127.3	< .1	< .1
0.1-1.0	9	2.3	55.1	1.1	43091.4
> 1.0	3	100.2	413.5	1.1	< .1
TOTAL	48	102.8	601.3	2.2	43091.4

* flow in million gallons per day (MGD). 1 MGD = 0.044 m^3/sec.

** tonnes/year.

† the large chloride load is primarily due to salt mining operations.

Note: Totals may not add up exactly due to rounding errors.

10.4 Distribution of Net Unit Loads

If the regional variability of stream quality is to be assessed, some estimate of net unit load (unit area load of the net change in transport between adjacent stations) must be made for each subwatershed. The net unit load (L_{ui}) is defined as:

$$L_{ui} = \frac{L_i - \sum_{j=i+1}^{n} L_j}{A_i - \sum_{j=i+1}^{n} A_j}$$

where:

L_i = gross load at sampling station i.

A_i = total area upstream of station i.

L_j = gross load at next upstream station j.

A_j = areas upstream of station(s) j.

The net unit load (kg/ha/yr) can be positive or negative. Figures 12 through 14 show the distribution of net unit loads for study year 1975 for total phosphorus, chloride and suspended solids.

10.5 Delivery Ratio

PLUARG studies have attempted to quantify delivery ratio. Delivery ratio is defined as the ratio of material delivered by a flowing waterway to the material potentially available to be delivered by a waterway. The difficulties

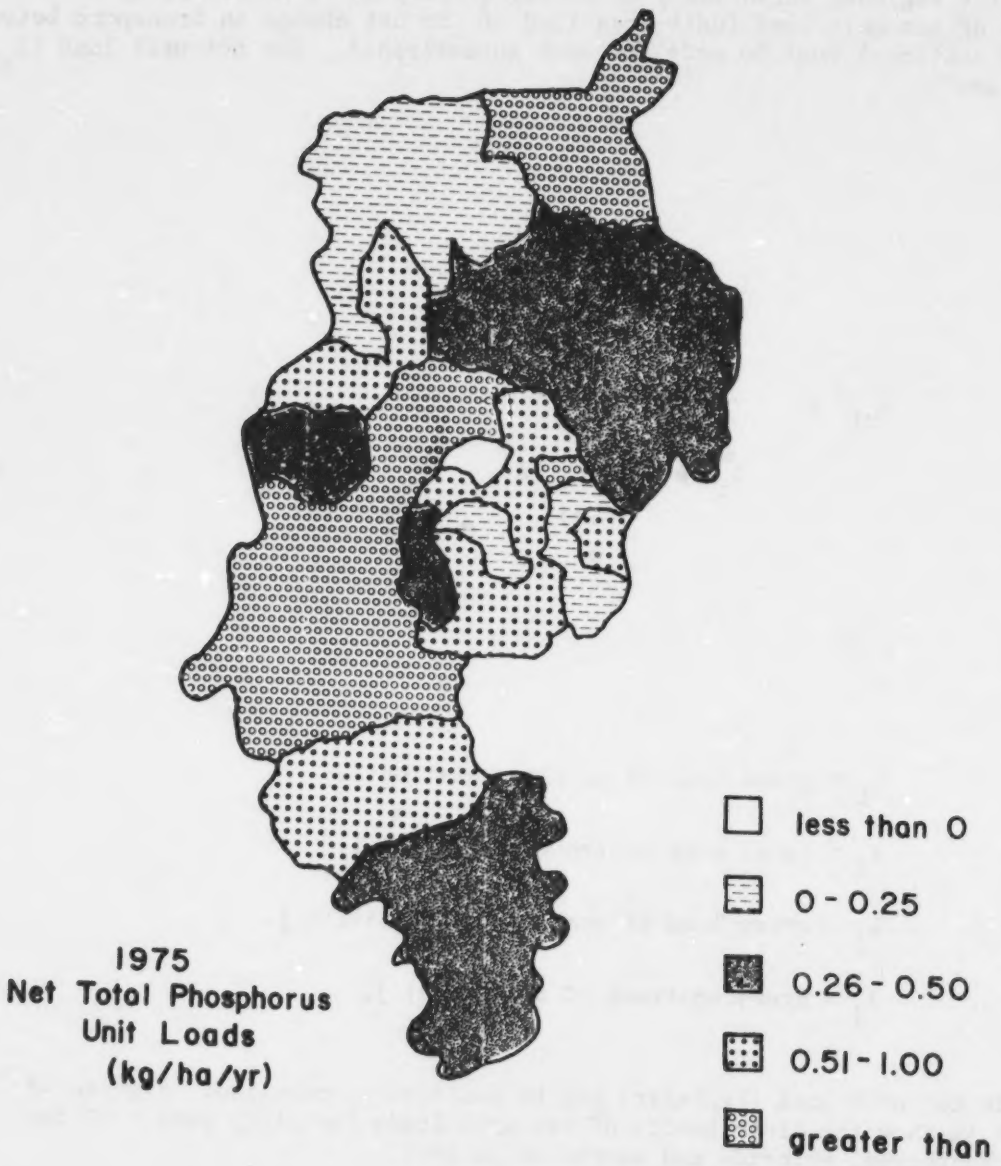

Figure 12. Study Year 1975-Net Total Phosphorus Unit Loads

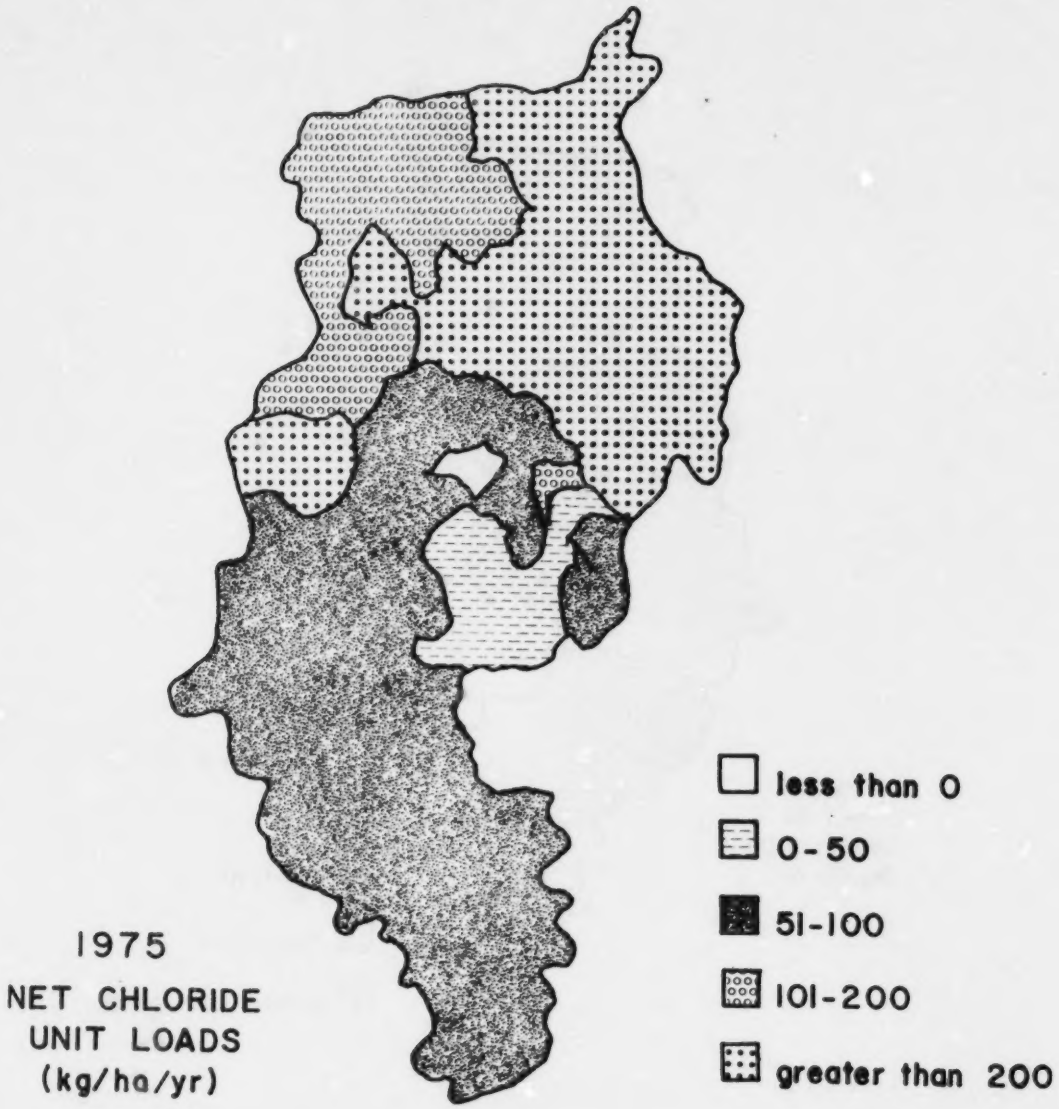

Figure 13. Study Year 1975-Net Chloride Unit Loads

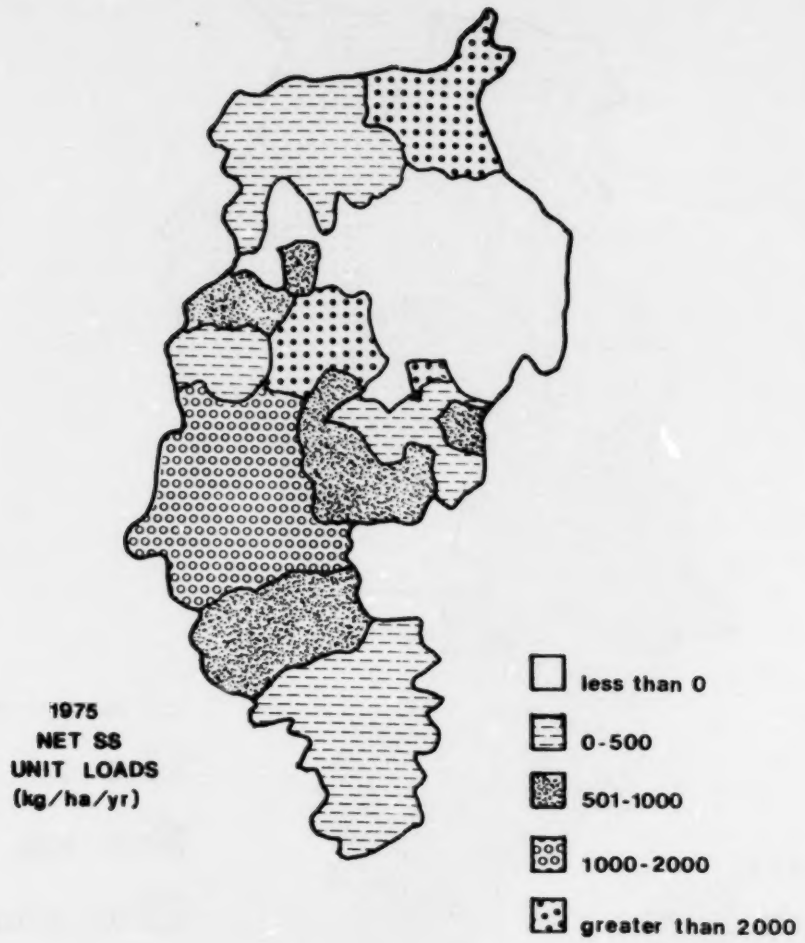

Figure 14. Study Year 1975-Net Suspended Solids Unit Loads

in measuring overall delivery ratios have confined studies to estimation of instream delivery ratio only, and a conservative assumption that the instream delivery ratio is equal to 1; i.e. any material delivered to a waterway is ultimately discharged to the Great Lakes.

Estimates of potential river mouth loadings for the parameters of concern were developed by constructing isoplethal maps of unit area loads for the Genesee Watershed. The maps were drawn using data from the most upstream station on a given stream. Sources of this data were the routine sampling network, a synoptic survey (Section 10.6.5), the DEC-IFYGL Study (Hetling, Boulton and Carlson, in press), the DEC Monitoring and Surveillance Network (Maylath, 1976) and the United States Geological Survey (USGS, 1975 & 1976).

10.5.1 Suspended Solids

Although variation in the nature and chemistry of suspended solids, phosphorus and chloride required that each be handled separately, suspended solids were used as a basis for estimating the loads for particulate and soluble phosphorus.

The historical development of delivery ratio is related to the development of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965). This equation estimates the gross annual potential for sediment production off the land, and this, compared to the sediment discharged at the mouth of a watershed, is considered the sediment delivery ratio for the watershed. The Universal Soil Loss Equation, in conjunction with the routine sampling synoptic survey data, was used to estimate the annual sediment unit load delivered from 59 upland synoptic survey watersheds.

The estimated annual suspended sediment load was related to the synoptic survey data using the New York State Erosion and Sediment Inventory (EASI) (USDA, 1974) as the common denominator. Unit suspended sediment loads for each of the 59 synoptic survey watersheds, were calculated and an isopleth map of unit load developed (Figure 16). Figure 15 shows schematically how the calculation was made.

The annual load predicted by this method is 609,000 tonnes. This compares to measured loads of 1,014,350 tonnes in 1975 and 544,427 tonnes in 1976 or 60 percent and 112 percent (Table 8). The difference between the 1975 and 1976 suspended solids loads serves to show the variation in the system. Prediction by this method gives an estimate of the order of magnitude one might expect on an annual basis. Total flow for 1976 was some 30 percent less than 1975, so that the reduced load might be expected, particularly for suspended material, given its dependence on flow. Further, it is reasonable to expect that the sediment carrying capability of the river was reduced more than the absolute flow reduction causing a nearly 50 percent reduction in sediment delivered.

In calibration of a model such as this to upland watersheds, one would expect an overestimation of load because smaller watersheds generally produce higher suspended solids unit loads than larger drainage basins (Gregory and Walling, 1973). There is, however, evidence (Keller and Gilbert, 1967) that the main stem of the Genesee River is an active sediment producer, particularly in the central basin. If this is true, use of upland watersheds for calibration would exclude

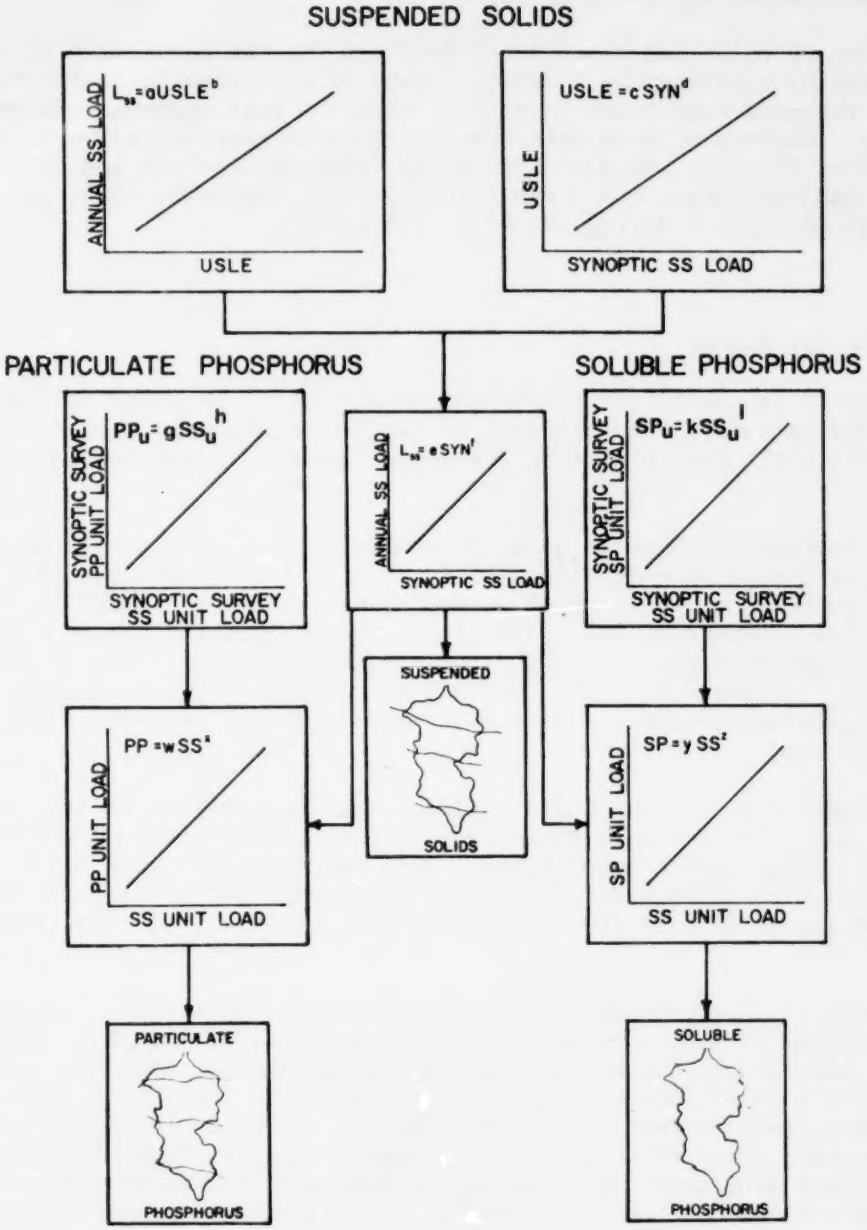

Figure 15. Unit Load Calculation Flow Chart

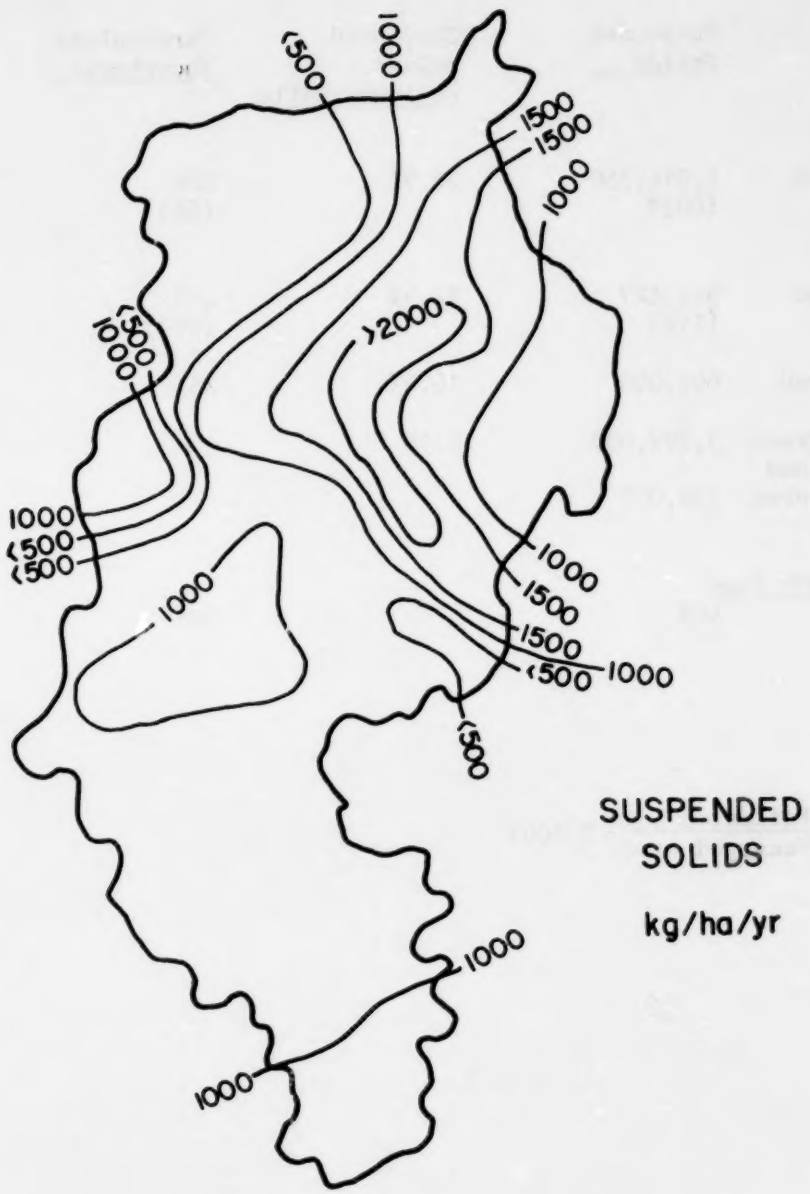

Figure 16. Estimated Suspended Solids Unit Load

Table 8. Suspended Solids and Phosphorus Load Estimates

Load	Suspended Solids	Suspended Solids Delivery Ratio	Particulate Phosphorus	Dissolved Phosphorus
1975 Measured Load	1,014,350 (60)*	26.7%	686 (66)	127 (83)
1976 Measured Load	544,427 (112)	14.3%	417 (109)	107 (98)
Estimated Load	609,000	16.0%	454	105
USLE/EASI Load gross load	3,799,000	8.7%		
Delivered load	332,000			
1975 Load-1976 Load / 1975 Load	46%		39%	16%

*(Percent)= $\frac{\text{Estimated Load}}{\text{Measured Load}}$ X 100%

a major sediment source.

It is interesting to note that the Erosion and Sediment Inventory (USDA, 1974) predicted a gross potential load of 3,799,000 metric tonnes. Using the delivery ratio based on watershed size (Gregory and Walling, 1973) for each of the sub-watersheds as defined in the EASI study, the predicted load was 332,000 tonnes for an overall delivery ratio of 8.7 percent. Using the measured loads and the EASI gross production potential estimate, the delivery ratio ranged from 14.3 percent (1976) to 26.7 (1975) and was 16.0 percent for the estimated load (Table 8). Clearly, there is much to be learned about erosion dynamics and sediment transport.

10.5.2 Phosphorus

Unlike sediment, no tool (i.e. the Universal Soil Loss Equation) exists for estimating the gross production potential for chemical parameters. For this reason and due to the nature of the chemical and physical dynamics of phosphorus in streams and rivers, the load estimation was related to suspended solids production.

Phosphorus load was divided into its particulate and soluble components to produce separate loads.

Synoptic survey suspended solids unit loads were related to the synoptic survey particulate phosphorus unit loads as shown in Figure 15. From these unit loads, the particulate phosphorus contour map was developed (Figure 17).

The predicted annual load for particulate phosphorus was 454 tonnes. This compares to 686 tonnes in 1975 and 417 tonnes in 1976. On a percentage basis, the estimated load was 66 percent of the 1975 load and 109 percent of the 1976 load. This range of variation is about 20 percent less than the variation of the measured loads about the suspended solids estimated load. The difference between the 1975 and 1976 particulate phosphorus loads is 39 percent as compared to 46 percent for the suspended solids.

As with the suspended solids estimate, the particulate phosphorus load estimate likely underrated the loads contributed within the lowlands. An additional error results for not including wastewater particulate phosphorus which, based on the point source inventory, may range as high as 24 tonnes per year.

Soluble phosphorus concentrations from the synoptic survey were also related to suspended solids in a manner similar to particulate phosphorus (Figure 17). The soluble phosphorus unit loading contour map is shown in Figure 18.

The soluble phosphorus estimate was 105 tonnes which compares to 127 tonnes (1975) and 107 tonnes (1976). Immediately apparent is the narrow range of variation of the measured loads around the estimated load with 1975 at 83 percent and 1976 at 98 percent, and only 16 percent difference between the two annual loads. Soluble parameters tend to be less variable with flow and, perhaps, more predictable.

Since the soluble phosphorus load includes no point source influences, it actually overestimates the load by a wide margin. The point source survey suggests a total phosphorus load of about 119 tonnes and thus a soluble phosphorus load of 95 tonnes. From this a total soluble phosphorus load of 200 tonnes might

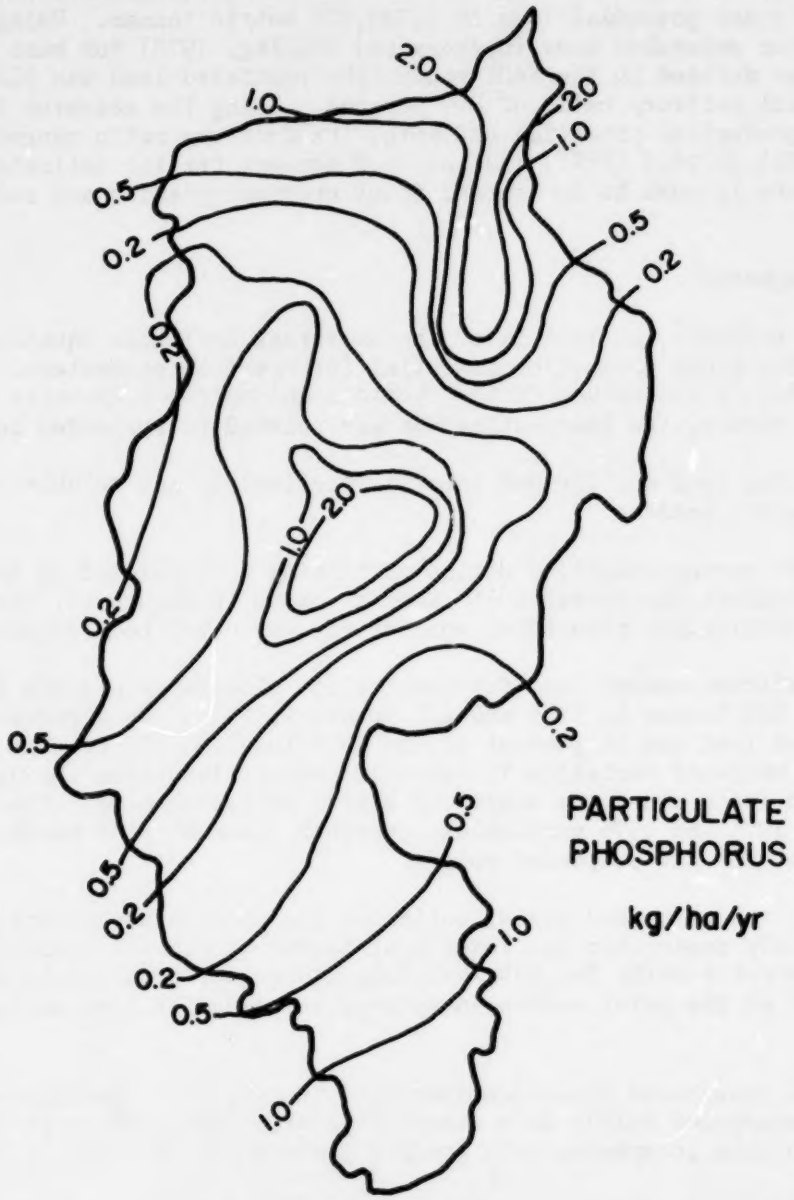

Figure 17. Estimated Particulate Phosphorus Unit Load

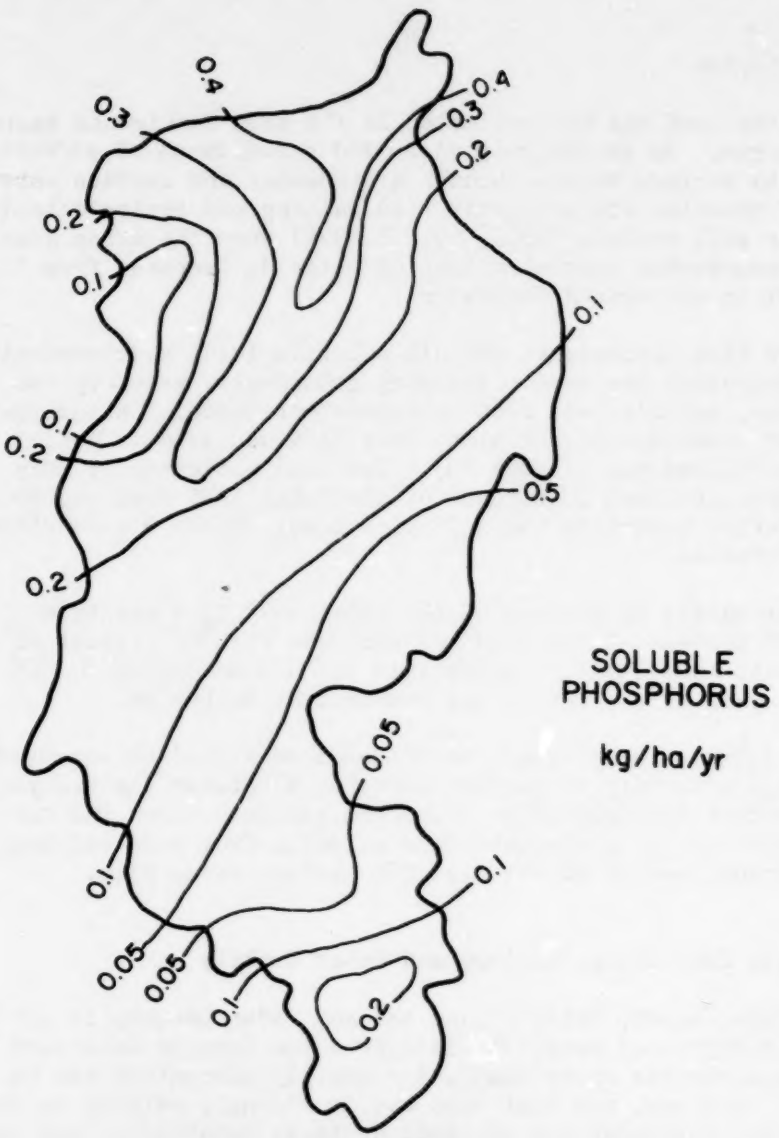

Figure 18. Estimated Soluble Phosphorus Unit Load

be expected at the mouth of the Genesee River on an annual basis. Since this load is not realized, it is possible that up to 60 percent of the soluble phosphorus input to the river is processed within the system so that it appears as particulate phosphorus or is bound up in the bed sediments and not measured.

10.5.3 Chloride

Chloride load was not estimated in the same fashion as suspended solids and phosphorus. As an entirely dissolved constituent of streams, it finds its way into surface waters through groundwater and surface water flow. The sources of chloride are primarily road salting and geologic/land use sources. Groundwater well records (USGS, 1975 & 1976) show the steep gradient south to north as groundwater concentrations of chloride increase from 10 mg/l to upward of 400 mg/l in and around Rochester.

Rather than estimate an overall chloride load, a determination of groundwater contribution was made. Assuming groundwater makes up the surface water at base flow, monthly base flow estimates were made. In combination with the groundwater chloride conentration, this flow was used to define a base flow chloride unit load map (Figure 19). The load estimated by this method was 35,000 tonnes or about 30 percent of the total 1975 load and 50 percent of the 1976 load after deducting the salt mine load. Table 9 summarizes the chloride load distribution.

Approximately 40 percent of the total 1975 flow was base flow and by subtraction 70 percent of the load was produced with 60 percent of the flow. This then suggests that runoff (mostly road salt) contributes 34,000 to 75,000 tonnes per year of the total load measured at Rochester.

Like soluble phosphorus, the annual load variation was over a rather narrow range with only 12 percent difference between the two years. This compares to a 46 percent difference for suspended solids between the two years. The extensive pollution of groundwater, principally from road salting, provides a large reliable annual source of chloride for surface water flow.

10.6 Land Use, Soils, Geology and Water Quality

The relationship between land use and water quality is not often clearly defined. Analysis of available data from the Genesee Watershed from the present and previous studies shows that water quality parameters can be related to factors other than land use, and that land use is strongly related to those other factors; e.g. geology, soil reaction pH, soil drainage capability, and topography as stream slope. Relationships between water quality, land use (as percent undisturbed land) and these factors were investigated. Arbitrary indices quantify the relative variation of each of the factors within the Genesee basin (Table 10).

Table 10. GEOLOGY AND SOIL INDICES

Parameter	Scale and Basis	
Geology	2-7	bedrock calcium content
Soil pH	5.5-8	soil reaction pH
Slope	0.7-4.8	stream bed slope - %
Drainage	5-9	soil drainage capability

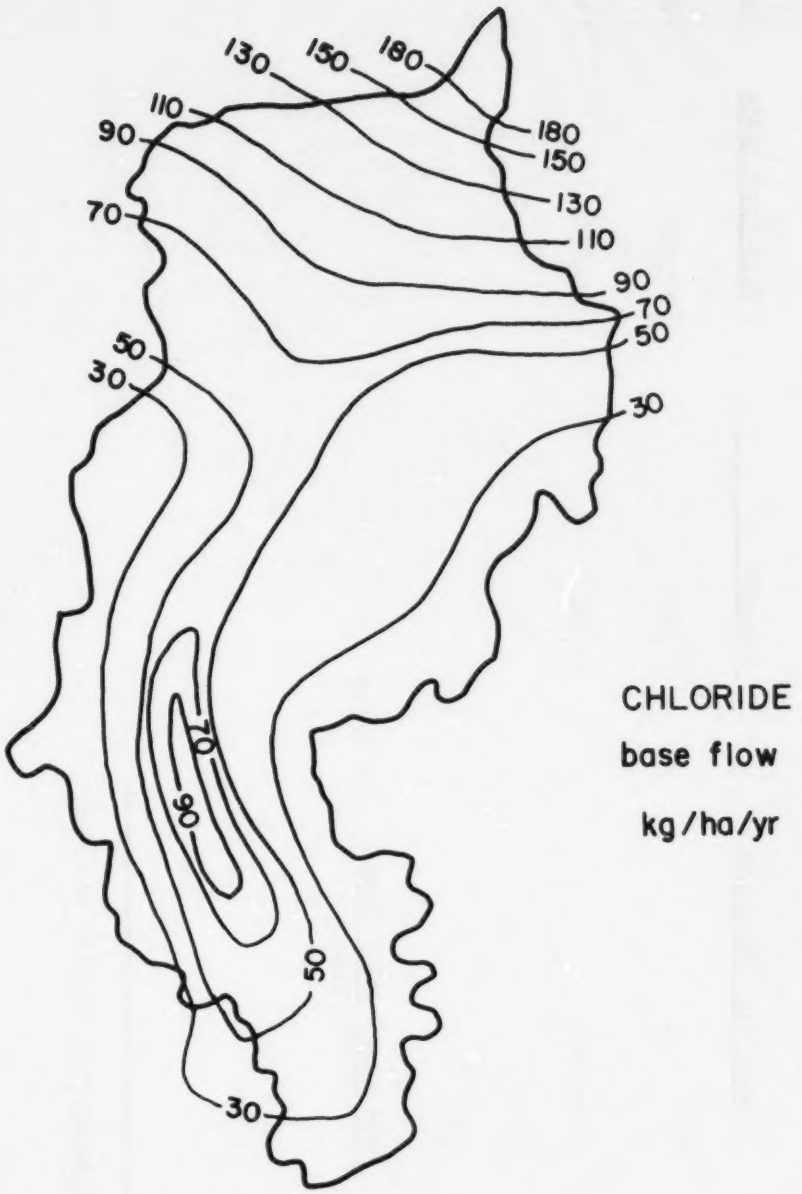

Figure 19. Estimated Chloride Unit Load

Table 9. Chloride Mass Balance

Study Year	Base Flow Chloride	Runoff*	Salt Mine Waste	Total
1975	35,000	74,800	17,000	126,800
1976	35,000	34,000	43,000	112,000

$$\frac{\text{1975 Load - 1976 Load}}{\text{1976 Load}} \times 100\% = 12\%$$

---

* Calculated by subtraction (mostly road salt).

Chloride (Cl) and total soluble phosphorus (TSP) typify the kinds of inseparable relationships that exist among the various factors. Figure 20 demonstrates the strong influence of land use on mean annual chloride concentration for six watersheds. There is a very sharp decrease from the three watersheds with relatively intense land use to those having diminished levels of activity. The log coefficient of variation of chloride concentration shows a similar relationship, with increasing variation of Cl concentration about the mean with increasing undisturbed land. It is evident that land use activities are strongly correlated with the concentration and variability of chloride in surface waters (Figure 20). In watersheds where seasonal use varies widely, large variations in stream concentrations are found.

Figure 21 depicts the relationship between chloride concentration and the geology index and soil drainage capability index. Chloride shows a positive linear relationship with geology which is due in part to the distribution of evaporites as halite in the northern and north central portion of the Genesee watershed. Chloride is also positively related to soil drainage capability. Chloride tends to migrate to streams through subsurface flow; well drained soils will tend to deliver chloride in a shorter time than poorly drained soils.

Total soluble phosphorus (Figure 22) follows a steep negative variation with increased percent undisturbed land. This is the type of relationship one expects of phosphorus as it demonstrates the impact of civilization on TSP input to streams. The TSP log coefficient of variation follows a positive relationship with increasing undisturbed land. Low levels of TSP in the forested lands as compared to urban land, are responsible for the increased coefficient of variation. Small fluctuations about the low mean TSP concentration in an undeveloped watershed can cause a great change in the coefficient of variation. The calcareous nature of the system also likely plays a part in stabilizing the TSP concentration.

Geology index and soil pH index (Figure 23) have significant effects on the variation of total soluble phosphorus. Both variables induce a negative linear model with the TSP log coefficient of variation. The negative relationship indicates a stabilizing capability that is likely related to the increasing calcium content of both the parent bedrock and surface soils. Other work (Carlson, 1977) has demonstrated the binding capability of the calcareous stream bed sediments found in the northern portion of the Genesee basin.

All of these water quality relationships may be reasonably explained, but it can be similarly shown that land use is related in turn to each of the indices described. Figure 24 shows the relationship between soil pH index and land use and Figure 25 shows the relationship between geology index and land use. The geologic index follows closely the variation in land use that has developed in the Genesee River Basin as does soil pH. In addition to these relationships, it can be seen (Figure 26 and 27) that both slope index (stream gradient) and soil drainage capability index (Figure 26) are closely related to land use. With these relationships it is evident that there is a strong interdependence among many parameters in defining surface water quality.

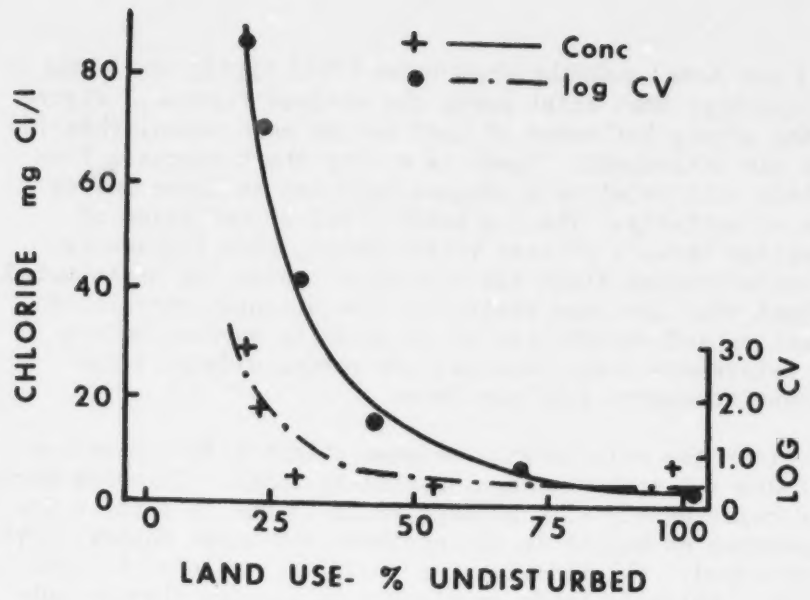

Figure 20. Chloride Concentration vs. Land Use

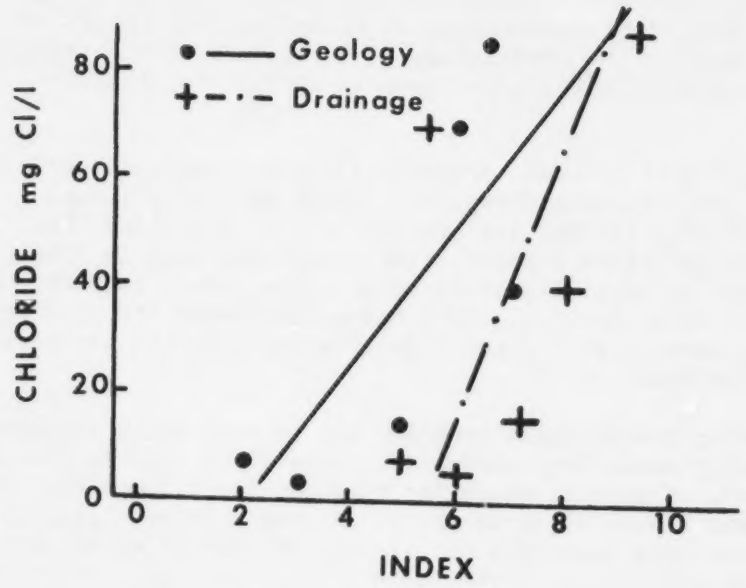

Figure 21. Chloride Concentration vs. Geology Index & Soil Drainage Index

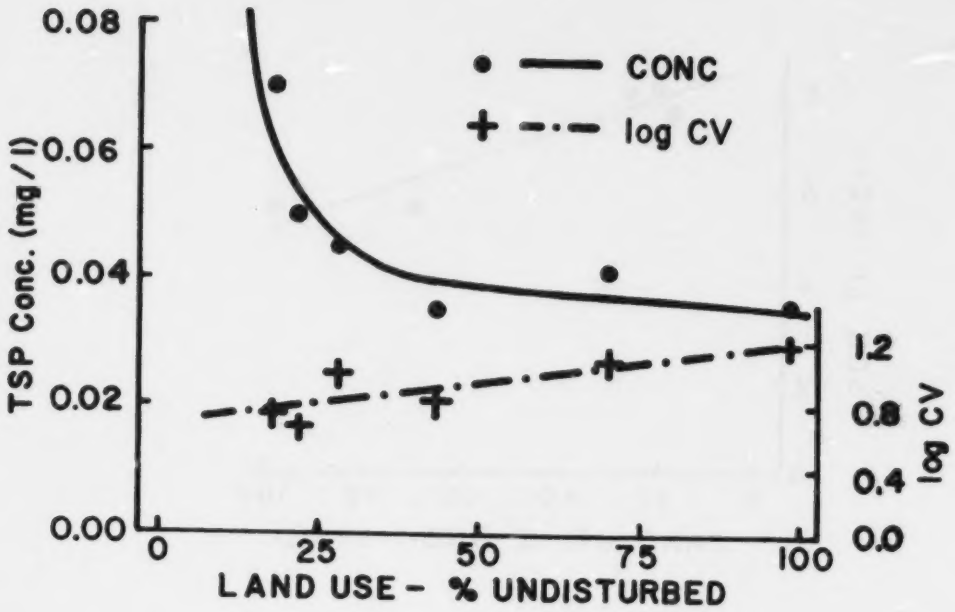

Figure 22. Total Soluble Phosphorus vs. Land Use

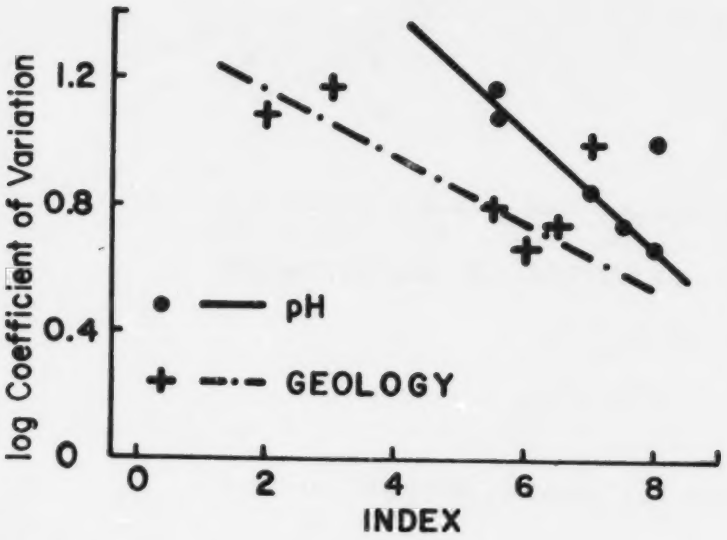

Figure 23. Total Soluble Phosphorus log Coefficient of Variation vs. Geology Index and Soil pH Index

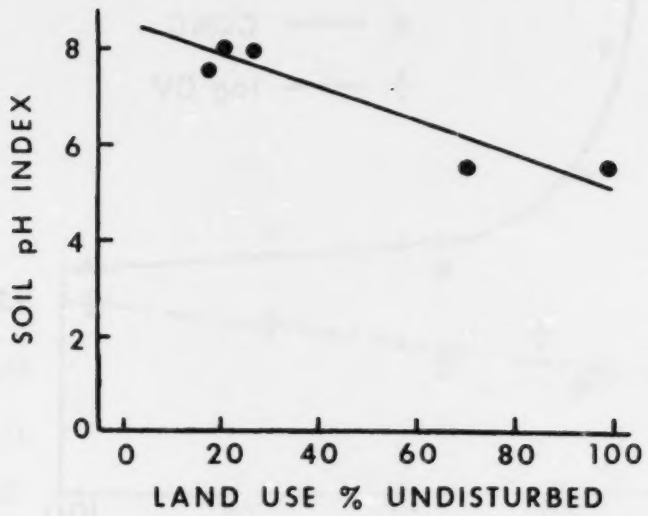

Figure 24. Soil pH Index vs. Land Use

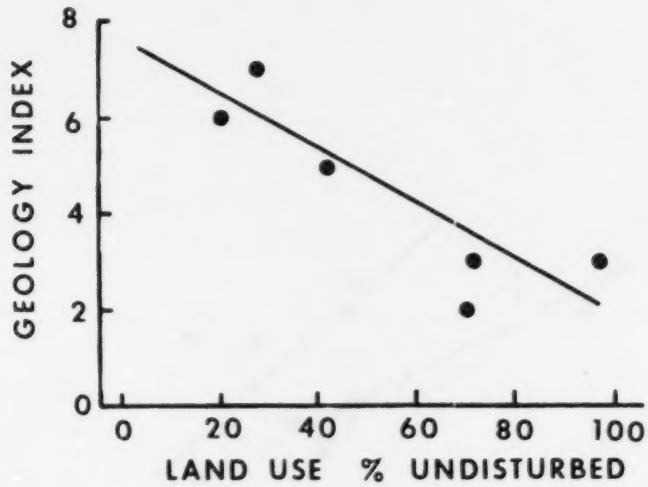

Figure 25. Geology Index vs. Land Use

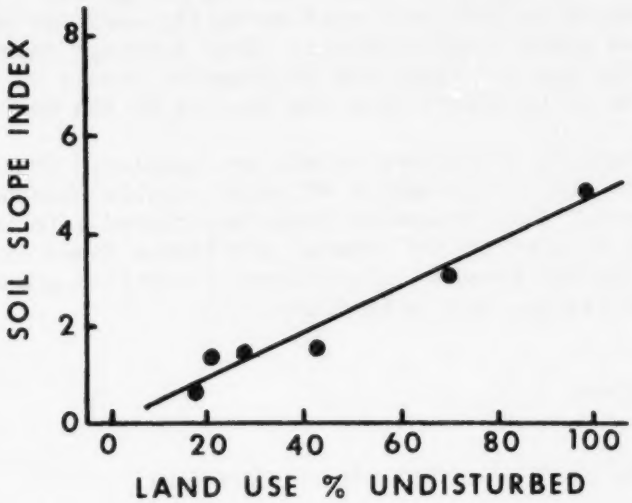

Figure 26. Slope Index vs. Land Use

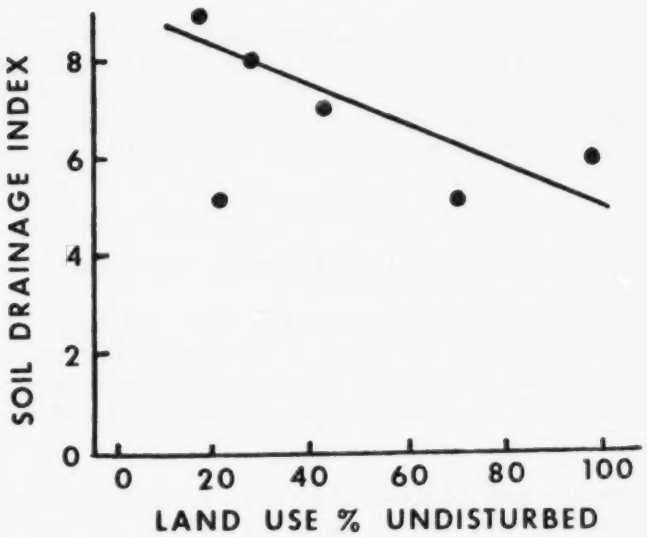

Figure 27. Soil Drainage Index vs. Land Use

Chloride shows a very strong relationship to land use. One can usually identify the likely and anomalous sources of this ion (point sources and unprotected salt piles), but in conjunction with the land use/chloride interaction, the variation with geological development must be recognized. The presence of large evaporite deposits in the north most certainly modifies what might otherwise be lower surface water concentrations. Soil drainage capability also must be considered as affecting the variation in chloride levels in the streams and as a control of the rate of transport from the sources to the surface water.

Phosphorus variations in surface waters are complex. There is no question that land use affects the concentration of total soluble phosphorus in the Genesee surface waters. High levels in areas associated with intense land use activities cannot be related to the natural conditions found in the watershed. The total geologic system, however, significantly modifies groundwater and surface water concentrations and variability.

10.7 Special Studies

10.7.1 Water Quality Studies at Mill Creek, New York

Two special studies were conducted at Mill Creek, a small stream draining 2,500 hectares in Rensselaer County near Albany, New York. The land use in the watershed is predominantly forest (54%) and agriculture (43%). The stream is unregulated and has no known point sources of pollution. A complete description of the watershed is available (El-Baroudi et al., 1975).

The first study involved rigorous water quality sampling to determine the influence of sampling interval on the estimation of annual loads and average water chemistry (10.7.1.1). The second study consisted of an inventory of the forms of phosphorus and nitrogen in the Mill Creek Watershed, including a simple block diagram conceptual model for phosphorus flux during an average year (10.7.1.2).

10.7.1.1 Sampling Interval Studies at Mill Creek, New York

The purpose of this study was to estimate what influence sampling interval has on the estimation of the annual loads of suspended sediment, chloride and phosphorus from a watershed. Many past stream water quality studies have used an experimental design based upon balancing the temporal and spatial variation in stream chemistry.

Problems of logistics and limited resources have forced most investigators conducting stream chemistry studies to sample at fixed intervals, usually bi-weekly or monthly. In an attempt to make empirical estimates of errors associated with fixed interval sampling, Mill Creek was sampled once a day from June 2, 1975 to May 31, 1976. Twenty water quality constituents were analyzed including major ions and the various forms of carbon, nitrogen and phosphorus. Stream discharge was also measured by a standard stage height recording gauge.

Average daily loadings were calculated for ten subsets of data taken at fixed intervals of one to 60 days. The calculations are described in Hetling, Carlson and Bloomfield (1976). The results of these calculations for stream discharge, chloride, phosphorus and suspended solids are shown in Figures 28-36.

It is apparent from these results that for runoff event related parameters such as total phosphorus and suspended solids, one must sample very frequently (at least every other day), or the average values calculated from data will vary considerably from the actual daily average. The error associated with infrequent sampling is worst in the calculation of loadings of particulate constituents. Order of magnitude or greater errors can be encountered for these parameters with less than a three day sampling interval (Hetling, Carlson and Bloomfield, 1976).

As a result of this analysis, it can be concluded that for small streams such as Mill Creek, fixed interval sampling for variable components such as suspended solids and particulate phosphorus, to obtain average concentrations, is of little value unless the sampling interval is less than three days. Attempts at fixed interval sampling should be discouraged in favor of runoff event sampling covering a wide range of discharge conditions.

10.7.1.2 Inventory of Forms of Nutrients Stored in a Watershed

An inventory of the organic and inorganic forms of nitrogen and phosphorus was carried out on the Mill Creek Watershed (El-Baroudi et al., 1975). Results show that nutrients in terrestrial systems encounter periodic transformations and exchanges with adjacent water resources depending on both natural processes and the activities of man. Also, a nutrient inventory is enhanced when information on nutrient availability and seasonal transfer rates are included.

Figure 37 depicts an annual phosphorus budget for Mill Creek based on collected data and best available literature information. The stream outflow value (1.84 tonnes per year) is further divided monthly in Figure 38. Annual total phosphorus inputs from external sources were estimated to be 3.82 tonnes while the total export was 3.84 tonnes. The stream TP discharge was 48 percent of the total output, but was less than 0.05 percent of the total phosphorus stored within the watershed. Nearly 70 percent of the TP discharge occurred between January and April.

10.7.2 Nitrogen and Phosphorus Losses in Drainage Water from Organic Soils (Duxbury and Peverly, 1977)

Organic or peat soils, which can be very intensively and profitably cultivated after adequate drainage, appear to be an important diffuse source for N, P and other elements in drainage water. Drainage water from two organic soil deposits was monitored for 15 months.

Results show total losses from the soils were as follows:

Molybdate reactive phosphorus	.9 - 30.7 kg/ha/yr
Nitrate nitrogen	41 - 92.6 kg/ha/yr
Ammonia nitrogen	1 - 1.9 kg/ha/yr

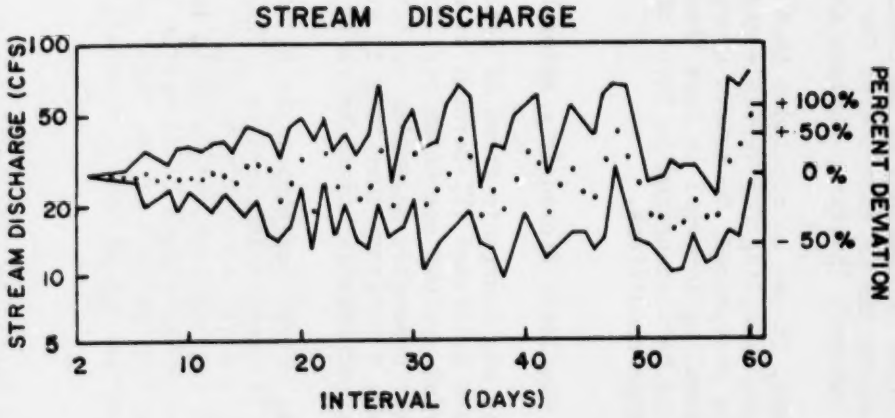

Figure 28. Mill Creek - Stream Discharge vs Sampling Interval

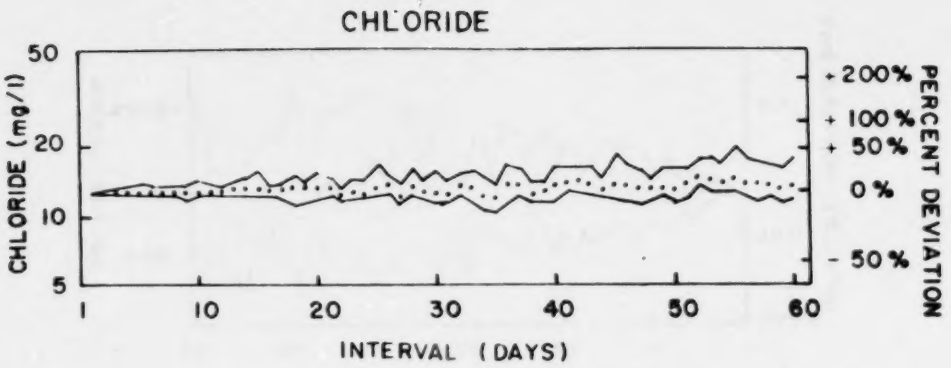

Figure 29. Mill Creek - Chloride Concentration vs Sampling Interval

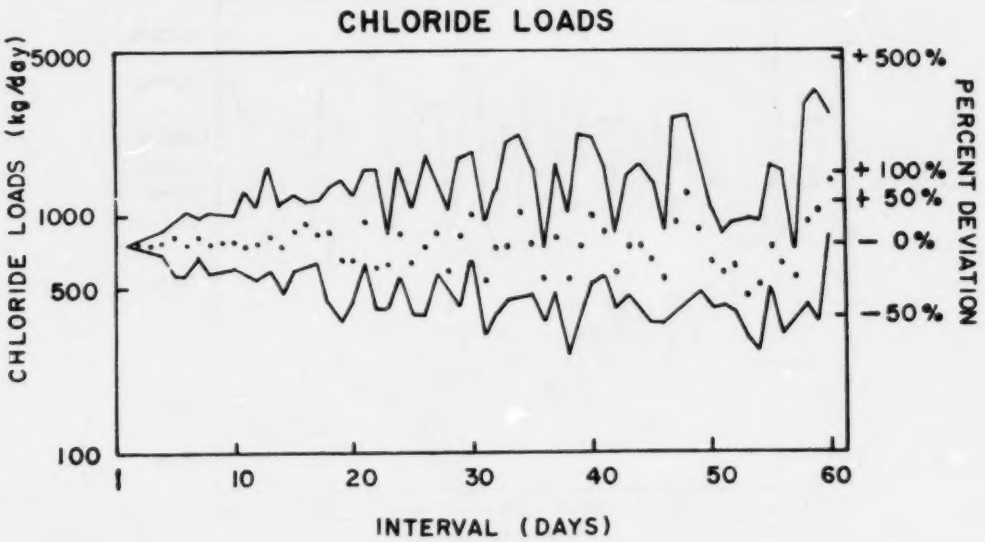

Figure 30. Mill Creek - Chloride Load vs Sampling Interval

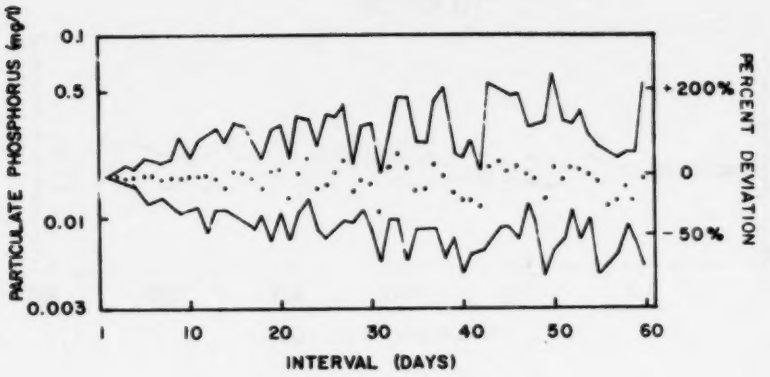

Figure 31. Mill Creek - Particulate Phosphorus Concentration vs Sampling Interval

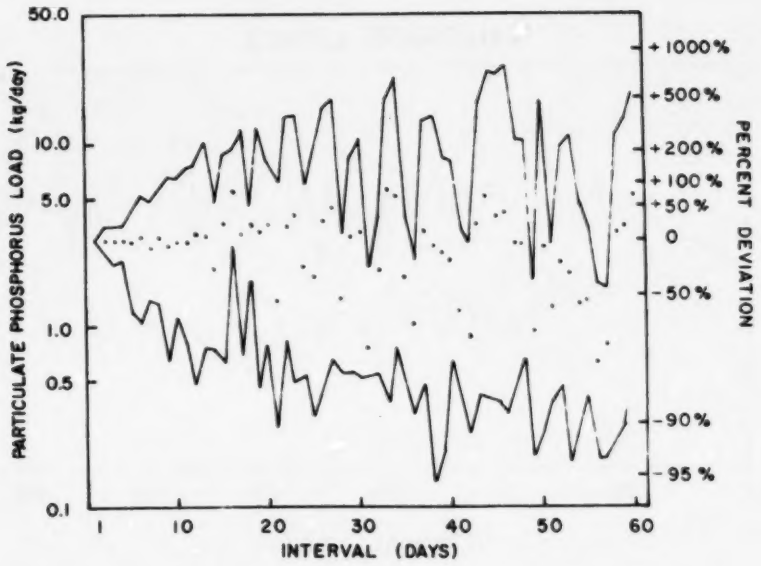

Figure 32. Mill Creek - Particulate Phosphorus Load vs Sampling Interval

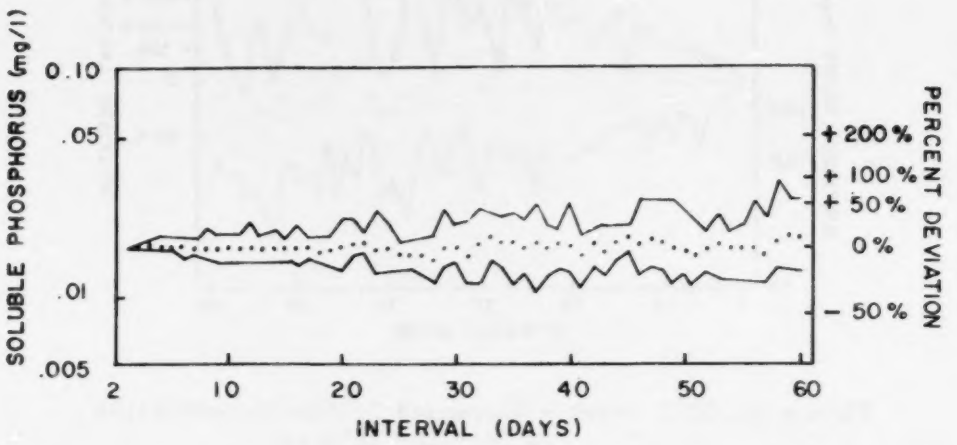

Figure 33. Mill Creek - Soluble Phosphorus Concentration vs Sampling Interval

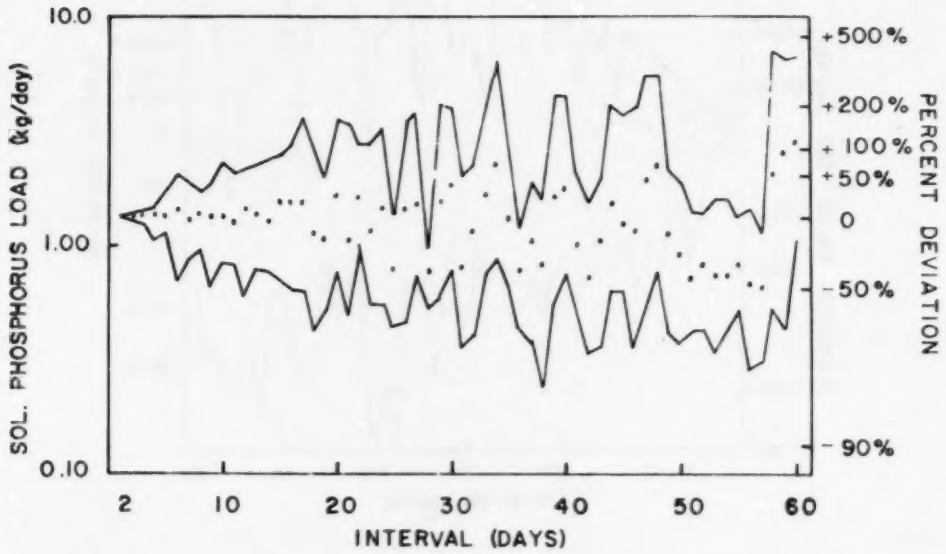

Figure 34. Mill Creek - Soluble Phosphorus Load vs Sampling Interval

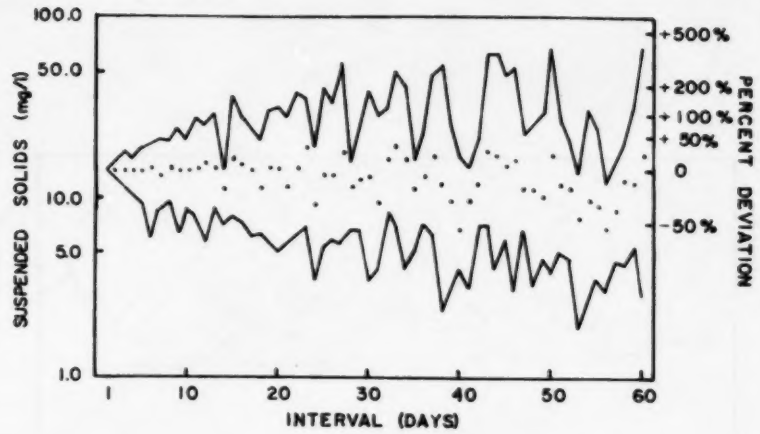

Figure 35. Mill Creek - Suspended Solids Concentration vs Sampling Interval

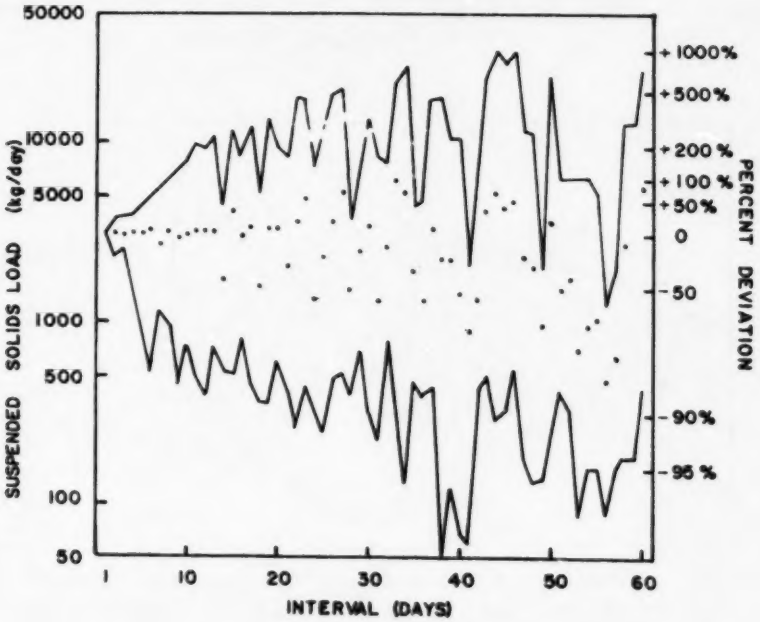

Figure 36. Mill Creek - Suspended Solids Load vs Sampling Interval

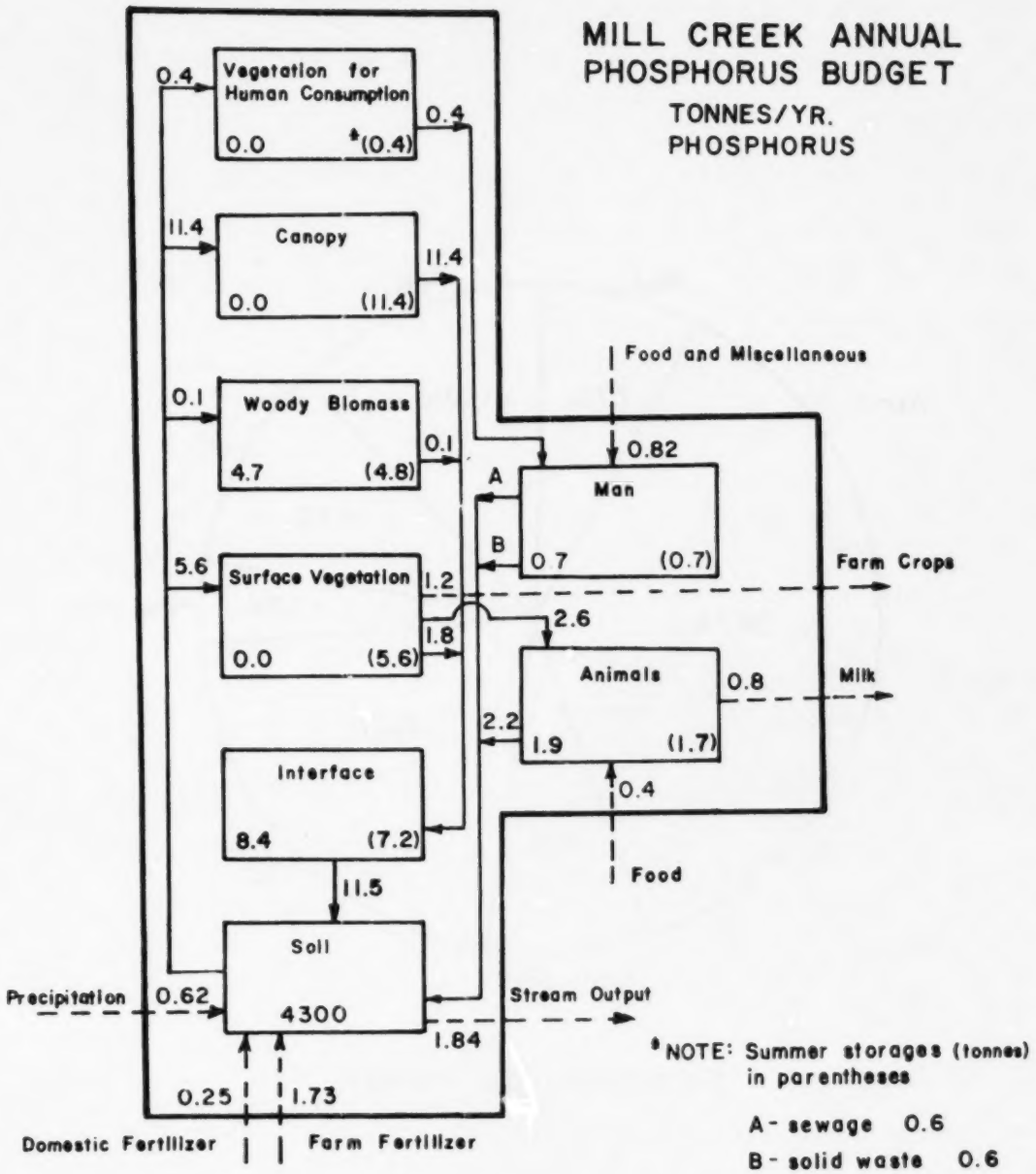

Figure 37. Mill Creek - Annual Phosphorus Budget

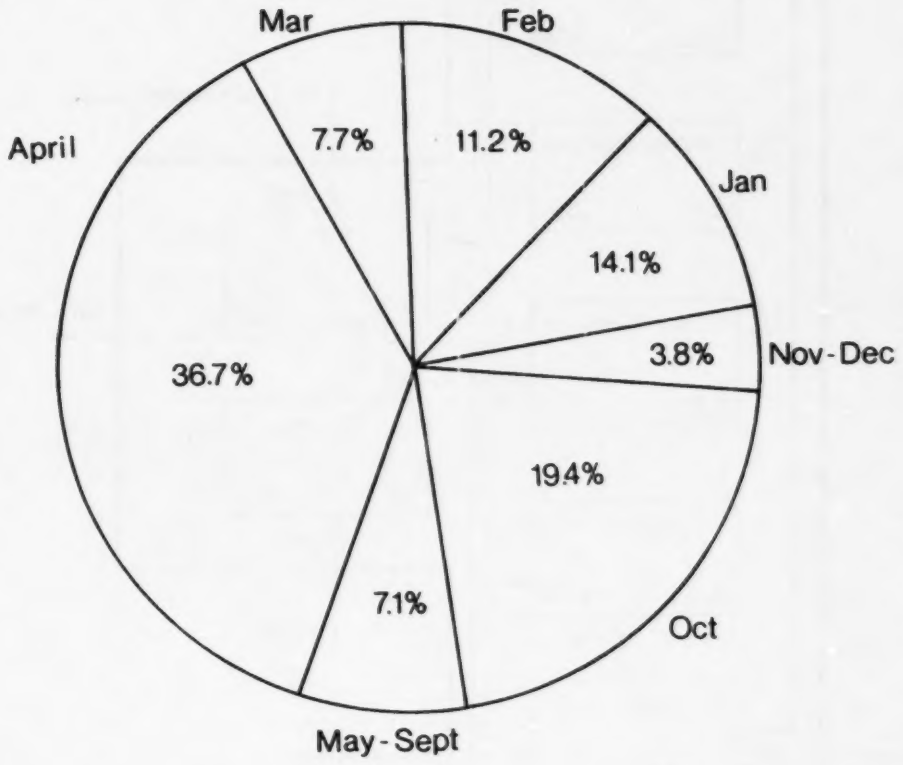

Figure 38. Mill Creek - Monthly Phosphorus Budget

P losses seem to be directly related to the depth of organic material. Appreciable quantities of metals may also be lost from certain organic soils.

Although relatively high concentrations of nutrients are released from organic soils, these soils only account for approximately 1 percent of the land area in the Genesee Watershed.

10.7.3 Nutrients and Heavy Metals in Genesee River Sediments (Reddy, 1977)

During the sampling period starting in April 1975 and ending in March 1977, 142 bottom sediment, 65 suspended sediment, 151 water column particulate, 152 water column unfiltered and 146 water column filtered samples were collected to assess the concentration, distribution and chemical characteristics of nutrients being transported by the Genesee River and its tributaries. The specific objectives were to provide: (1) information for analysis of the effect of land use activity on sediment composition, and (2) a basis for determining whether the metals and nutrients in the watershed sediments were present in high enough concentrations and were being transported in a reactive chemical form through the basin in such a way as to be a threat to the water quality of Lake Ontario. Sampling and analytical methods have been reported elsewhere (Krishnamurty and Reddy, 1975 and Reddy, 1977).

Metal and nutrient concentrations in the Genesee were generally indicative of a non-polluted environment. The exceptions were a moderate enrichment of phosphorus and a slight enrichment of lead. The phosphorus enrichment in the sediment arises both from agricultural activities and waste treatment effluents. Lead enrichment, in the predominantly non-urban setting, may be due to a diffuse atmospheric input and direct surface runoff from highway corridors.

Table 11 presents statistics for the phosphorus analyses of three types of sediment samples collected during routine surveys covering June 1975 through July 1976. This table shows that the largest sediment fractional phosphorus concentration is that extracted by hydrochloric acid. Ammonium oxalate-oxalic acid solution extracts somewhat less phosphorus from sediments, while sodium hydroxide and hydroxylamine extract much less.

The variation in total available sediment phosphorus concentration among the three sediment types shown in Table 11 is clearly apparent. Phosphorus content increases in the sequence: bottom sediment, resuspended bottom sediment, water column particulate material. This sequence follows the increase in the surface area of the three sediment types.

The concentrations of eight elements in bottom sediment from all stations in the watershed are summarized in Table 12. The mean sediment metal concentrations of the Genesee Watershed are compared in Table 13 with an average shale composition (Turekian and Wedephol, 1961) and with a typical lacustrine sediment containing carbonates (Förstner, 1977). Differences between the shale and lake sediments are due to a dilution effect, with carbonate minerals having lower heavy metal contents than shales. Reduction of the sediment metal concentration by carbonate dilution is reported to be greatest for iron and somewhat less for nickel, chromium, zinc and manganese (Förstner, 1977). This reduction sequence is seen in the Genesee Watershed sediments, suggesting that basin sediment trace metal contents are less than recognized reference values because of significant sediment concentrations of trace metal depleted minerals such as quartz

Table 11. STATISTICS FOR PHOSPHORUS ANALYSES
FOR SEVERAL SEDIMENT TYPES
COLLECTED IN THE GENESEE RIVER WATERSHED, NEW YORK (µg/g)

Sample Type	Concentration [a] Mean	Range	SD[b]	CV[c]	n
BOTTOM SEDIMENT					
Total Analysis	560	330-980	140	0.25	99
NaOH Extractable	58	5-410	62	1.07	98
HCl Extractable	398	177-731	99	0.25	98
NH_2OH Extractable	74	6-313	63	0.86	98
$(NH_4)_2C_2O_4$ Extractable	184	49-453	93	0.50	83
RESUSPENDED BOTTOM SEDIMENT					
Total Analysis	770	390-2020	360	0.46	46
NaOH Extractable	163	19-1000	232	1.43	17
HCl Extractable	528	258-664	109	0.21	17
NH_2OH Extractable	70	3-385	102	1.46	17
$(NH_4)_2C_2O_4$ Extractable	474	119-1110	222	0.47	17
PARTICULATE ANALYSIS					
Total Analysis	910	400-3000	640	0.70	61

[a] µg/g dry weight.

[b] SD, standard deviation.

[c] CV, coefficient of variation

Table 12. STATISTICS FOR TOTAL ANALYSES OF BOTTOM SEDIMENTS COLLECTED IN THE GENESEE RIVER WATERSHED

Parameter	Concentration[a] Mean	Range	SD[b]	CV	n
Aluminum	6,660	1,550-14,500	2,620	0.39	100
Chromium	14	10-79	9	0.66	78
Copper	18	8-41	7	0.40	82
Iron	15,060	2,350-36,500	7,312	0.49	100
Manganese	424	150-1,300	212	0.50	100
Nickel	23	6-87	13	0.57	98
Lead	40	6-550	67	1.69	99
Zinc	69	15-210	37	0.54	99
Total carbon	2.06	0.28-8.26	1.68	0.82	99
Total organic carbon	1.37	0.03-5.69	1.28	0.94	95
Total nitrogen	0.105	0.01-0.63	0.098	0.93	93
Phosphorus	0.0560	0.033-0.098	0.014	0.25	99

[a]For metals, µg/g dry weight. For nutrients, %.
[b]SD, standard deviation.

Table 13. MEAN METAL CONCENTRATIONS (µg/g) IN GENESEE RIVER WATERSHED SEDIMENT, AVERAGE SHALE COMPOSITION, AND TYPICAL LAKE SEDIMENTS RICH IN Ca-Mg CARBONATES

Metal	Genesee River watershed sediment	Shale[a]	Lake Sediment rich in Ca-Mg carbonates[b]
Iron	15,060	46,700	16,900
Manganese	424	850	475
Zinc	69	95	63
Chromium	14	90	42
Nickel	23	68	46
Copper	18	45	34
Lead	40	20	21

[a]Turekian, Wedepohl, 1961.
[b]Förstner, 1977.

and carbonates. Additional mechanisms for trace metal reduction may be geologic weathering and leaching of silt and clay fractions of the various minerals.

The higher mean value for lead in the Genesee Watershed sediments may be due to atmospheric inputs of lead transported from the highly industrialized central United States. Several lines of evidence indicate that point-source inputs of lead in the predominantly forested and agricultural basin are probably negligible (Hetling, 1976). Durum and co-workers (1971) have shown that in high-alkalinity surface waters, lead solubility will be low, and most of the rainfall and dustfall lead will be transferred to river sediments, where it will tend to accumulate.

10.7.4 Streamflow and Sediment Transport in the Genesee River Basin, New York (Mansue and Bauersfeld, written comm., 1978)

The U.S. Geological Survey has developed and maintained a hydrologic- and sediment-monitoring network within the Genesee basin which included determining sediment-size, loading-rate and mineralogical analyses of the sediment collected.

Streamflows during the study (1975-77) were generally at or near the monthly mean of the period of record at each station. Flows in the southern part of the basin were somewhat above normal during the spring of 1976.

Suspended sediment was measured at several types of stations as indicated in Section 9.2. Sediment production per unit of flow (kg/m^3) was higher in the upstream watersheds than further downstream. From April to September 1975, sediment yield (kg/ha) was 7 times greater at Portageville than 110 km downstream at Rochester and decreased steadily between these two sites. During the corresponding period in 1976, the yield at Portageville was 1.5 times greater than at Rochester. The ratio of yield at the Portageville to that at Rochester was 2.5 during the 1976 water year whereas the total loads at both sites were equal. The sediment yield decreased in inverse proportion to drainage area--a phenomenon observed at other streams by Gregory and Walling (1976) in conformance with the usual geomorphic pattern of degradation in headwater streams and subsequent aggradation at lesser gradients downstream.

Large sediment sources are available for erosion south of Portageville, whereas deposition occurs above the Mt. Morris dam and farther downstream in areas of lower river gradients. Downstream from the Mt. Morris dam, the floodplain widens and the channel gradient decreases to 0.2 m/km; as the river transverses the Huron Plain between Avon and Rochester, the gradient decreases to 0.02 m/km. Data collected on the Genesee main stem suggest that on a daily basis there is a several day lag and, on a monthly basis, a several month lag in the downstream movement of sediment.

The volume of sediment transported past the Portageville station decreased during the summer months but increased below the downstream sampling sites during the same period. From July to September 1976, total load transported past Portageville was the lowest of any 3-month period during the study; the highest load transported during this same time was past the Avon station which suggests a summer period of sediment migration through the river system.

The percentage of sand transported in suspension by the Genesee River is generally in direct proportion to the stream gradient. Twice the amount of sand was transported past Wellsville as past Portageville. The drainage area above Wellsville is predominantly sandstone, whereas above Portageville, the predominant sediment source is glacial drift of silt-size material.

The percentage of silt in transport was greater at the Portageville station than at the Mt. Morris station, although the percentage of clay- and sand-size material increased between these sites. The decrease in the percentage of silt is caused by its deposition behind the Mt. Morris dam; the increase in percentage of sand is attributed to the stream's flow over alluvial sands below the dam. Canaseraga Creek contributes a large percentage of the clay-size material measured at the Mt. Morris station.

The percentage of sand-size material measured at the Avon station is half that transported past the Mt. Morris station. This suggests sand deposition in the reach between Mt. Morris and Avon.

The percentage of sand transported by Catka Creek decreases in a downstream direction; this is a direct function of decreasing stream gradient.

Mineralogical analyses reflect the sources and age of material in the glaciated Genesee River basin. Quartz, illite and chlorite are the major constituents of the samples. Quartz is observed to be the dominant mineral transported in all but the lowest flows. This observation can be substantiated by its abundance and its high resistance to weathering. The shale, siltstone and sandstone that underlie the basin consist predominantly of quartz. The glacial till and lake deposits, which were eroded and transported by the glaciers, are derived from these sedimentary strata.

The major constituents of the basin are illite and chlorite. The predominance of these clay minerals reflect unmodified clays of the youngest glacial re-advance. The ratio of illite to chlorite was consistent in all analyses; the mean ratio was 2.72:1. The spatial variation in percentage of chlorite in the clay fraction showed, at a 95 percent confidence level, that the variation between locations cannot be differentiated from that within a single location, with one exception: At the Oatka Creek/Garbutt Station, a comparison of means of percent chlorite were significantly different under the Student t-distribution from those for other sites.

Calcite was found in samples from Canaseraga Creek tributaries. It is assumed this calcite was derived from the glacial drift composed of limestone eroded from the Onondaga Escarpment. During low flow, illite and quartz were the major constituents of sediment at the sites sampled.

10.7.5 A Synoptic Survey of Base Flow Water Chemistry in the Genesee River Watershed

It has been proposed that man's activities in a watershed influence stream water quality. What is often ignored are two related points. First, even in the absence of man's activities, certain regional trends in water quality exist, due primarily to heterogeneity in soil composition, but to a lesser extent on topography, bedrock chemistry and vegetational patterns. Secondly, man's usage of the land is highly related to both surface water quality and the geomorphologic factors mentioned previously. With this triad of land use, water quality and

geomorphology, it becomes difficult to isolate the land use-water quality leg of the triad from the other two. Intensive agriculture has often been indicated as a source of suspended sediment, nutrients and exotic chemicals to streams, but agriculture is generally limited to areas of certain soil types and topography. Therefore, it becomes difficult to select control watersheds in any stream chemistry study in agriculture areas.

Between June 28th and June 30, 1976, 59 unique stream watersheds in the Genesee Watershed were sampled once for 27 water quality constituents and stream discharge. These watersheds ranged in area from 15 to 207 km^2, but most were about 50 km^2. Land use ranged from almost entirely cropland to almost exclusively forest. Although the study was designed to evaluate regional trends in baseflow chemistry, a few streams were experiencing runoff events when sampled. This study is similar to a previous survey described in Bloomfield (1976).

Figures 39 to 42 show areal runoff, total dissolved phosphorus, chloride and calcium, respectively. These figures show general south to north trends in calcium and dissolved phosphorus, which could be explained by parallel trends in either land use (Figure 4) or bedrock geology (Figure 2).

Figure 43 is a bar graph comparing the chemistry of four groups of watersheds defined by land use (agriculture versus natural vegetation dominating) and bedrock geology (limestones and dolostones versus sandstones, shales and siltstones dominating). It appears that agricultural watersheds underlain by high lime bedrock exhibit the highest soluble phosphorus, calcium and chloride at summer flow conditions. However, without additional synoptic surveys conducted during several different flow conditions, it would be difficult to ascertain whether land use or natural factors are more important in defining the north-south water chemistry trend.

10.7.6 Geochemistry of Oxide Precipitates in the Genesee River Watershed (Whitney, 1977)

This work has as its principal objective the assessment of the function of manganese oxides as collectors of certain trace metals (in particular Zn, Cd, Co, Ni, Pb and Cu), entering the streams in solution from groundwater and runoff. Two types of samples were utilized; oxide-coated stream gravel and silt- and clay-sized stream sediments.

Hydrous manganese oxide coatings on the gravels were leached and the leachate analyzed for trace metals to ascertain the extent to which trace metal content of the oxides varies as a function of land use, and surficial and bedrock geology. Samples from 250 tributary streams in the Genesee Watershed were studied. Iron and the trace metals with the exception of lead correlate strongly with manganese. Lead shows a much weaker correlation and may be associated with a phase other than manganese oxides. Alternatively, environmental control on the abundance of Pb in the oxides may be sufficiently strong to obscure any correlations with Mn. Factor analysis yields a three-factor model accounting for 83 percent of the total variance of the data; Factor 1 (61%) is clearly controlled by Mn oxide abundance; Factor 2 (13%) is probably related to geologic variables; Factor 3 (9%) is dominated by Pb with lesser loadings for Cu and Zn, and is probably related to low-level environmental pollution. Multiple regression analysis of the gravels data indicates that Pb, Zn and Cu abundances are positively related to commercial, residential and industrial land use. Cd, Co and Ni are more abundant in forested areas than in areas of agriculture land use, although this effect may be due chiefly to geologic influences.

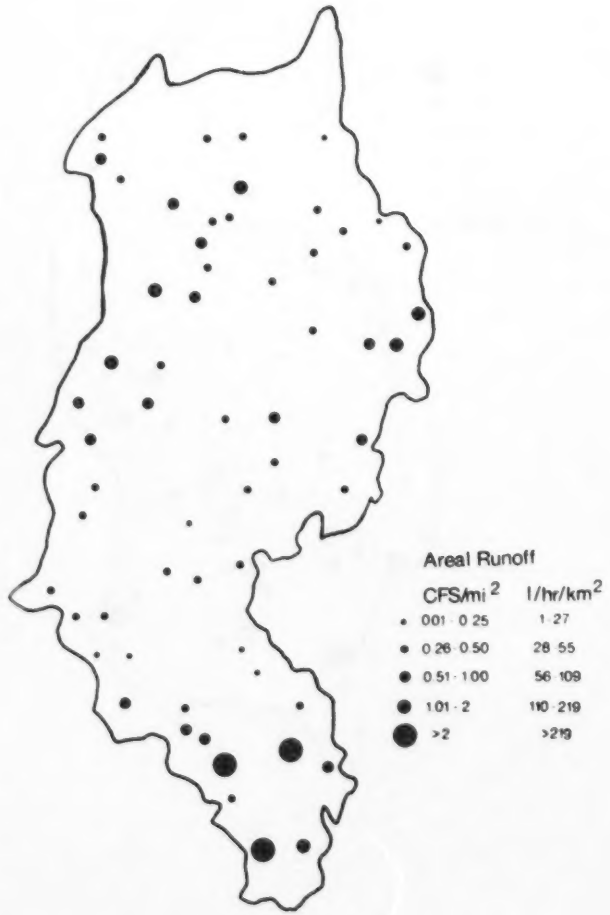

Figure 39. Synoptic Survey - Areal Runoff

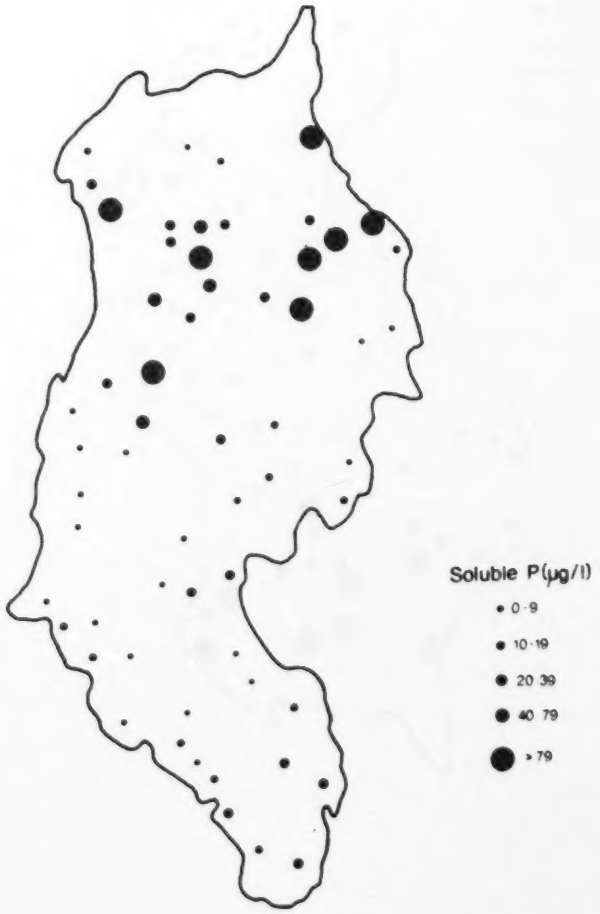

Figure 40. Synoptic Survey - Soluble Phosphorus Concentration

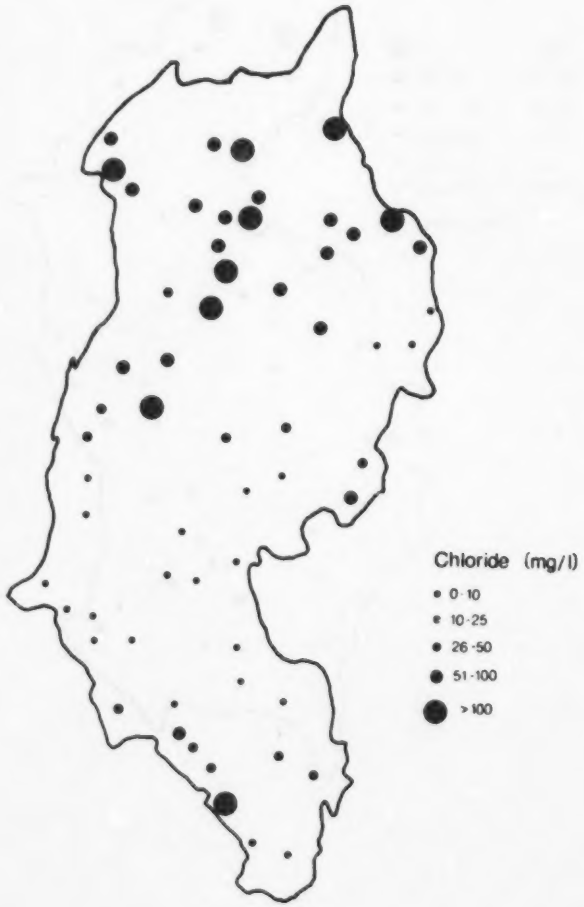

Figure 41. Synoptic Survey - Chloride Concentration

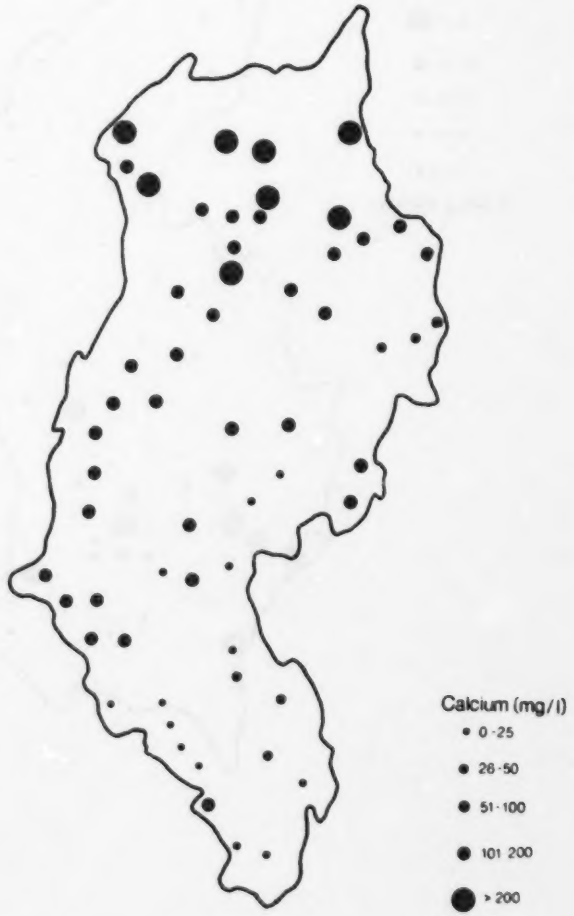

Figure 42. Synoptic Survey - Calcium Concentration

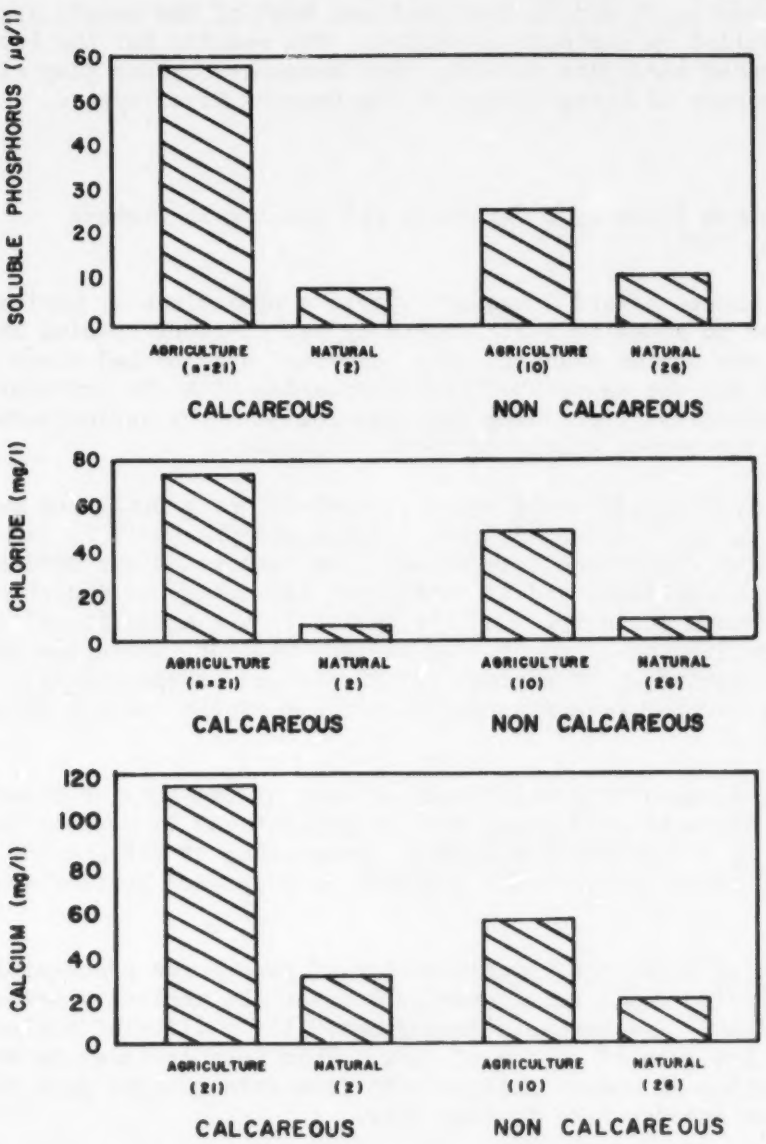

Figure 43. Synoptic Survey - Calcium, Chloride and Soluble Phosphorus vs. Geology

Hot nitric acid leaches of 130 samples of bottom sediments were also analyzed for the heavy metals and for Mn, Fe and Ca. Here, correlations of the metals with Mn was much weaker than for the gravels. Factor analysis yields a four-factor model accounting for 83 percent of the variance; the four factors appear to be linked with the four physical components of the sediments: silicates (Co, Ni, Cu, Pb, Mn); organic matter (Zn, Cd, Mn, Pb); oxides (Fe) and carbonates (Ca, Pb). Multiple regression shows a significant effect of commercial, residential and industrial land use on Pb and Cu distribution; most of the metals appear to be dominantly controlled by geologic variables. The results for the bottom sediments plus a few suspended sediments indicate that manganese oxides play at most a minor role in the transport of heavy metals in the Genesee River system.

10.7.7 Point Source Phosphorus Influence and Cycling in Streams (Bouldin, 1975)

Phosphorus inputs to and transport within a predominantly agricultural watershed were studied to identify major source types, nutrient species and species movement within the stream channel. The watershed studied had three major stations; one at the mouth and one on each of two tributaries with the tributaries having similar characteristics, (including land use dominated by agriculture) except for a substantial point source discharge to one tributary.

Using data from small, undisturbed watersheds and groundwater measurements, estimates of background values of total soluble phosphorus (TSP) and molybdate reactive phosphorus (MRP) were determined. The background was defined as biogeochemical phosphorus (BGP) and is considered indicative of phosphorus not associated with human activity. On this basis, in the agricultural watershed, 60 percent of the TSP and 45 percent of the MRP was BGP, while the point source watershed was estimated at 37 percent and 22 percent, respectively. At the watershed mouth, the BGP accounted for 50 percent of the TSP and 40 percent of the MRP.

Based on estimation from unit loads at each of the samples sites, MRP and TSP measured at the watershed mouth were 24 percent and 11 percent below the levels expected in a conservative system. Processing of MRP and TSP resulted in reductions of these species with transfer to suspended particulate and bed material.

Development of loads for identification of phosphorus processing required substantial analysis of the relationships between the various water chemistry parameters and flow. The analysis demonstrated the utility of including a term to account for time rate of change of flow. This term includes in the regression model, the variation of concentrations with flow rate changes as a storm hydrograph develops and then recedes back to base flow.

Use of this load calculation technique and the watershed mass balance indicated the positive effect the New York State phosphate ban had on reducing levels of this nutrient in wastewater and consequently, also in surface waters. The study also indicated the difficulty of identifying watersheds that were clean with respect to point sources. Particularly, intentional and accidental discharge of septic tank overflows to surface waters was found to be a continuous problem in all areas of the study watershed.

10.7.8 Stream Bank Erosion Study (Mildner, 1977)

Two subwatersheds in the Genesee Basin were studied to assess the magnitude of stream bank erosion and the probable contribution of eroded stream bank material to the overall suspended sediment load. About 17 percent of the stream bank of Canaseraga and Oatka Creeks were surveyed and estimates of total length of stream bank actively eroding and erosion rates were generated. From this, a best estimate delivery ratio was developed. These estimates, compared to sediment yield estimates provided by the United States Geological Survey, indicate that stream bank contribution to the Canaseraga and Catka Creeks is eight and four percent, respectively.

The investigation indicated that in the Canaserage Watershed, 308 bank kilometers are currently under treatment and another 74 need some treatment by Soil Conservation Service Standards. Catka Creek has 40 km requiring treatment compared to 73 km already under treatment. In both cases, the indicated treatment need was associated with modified stream banks and drainage ditches. This is also true of those sections with existing treatment; no existing or needed treatment was identified for the natural stream course.

It was shown for the watersheds studied, that excepting phosphorus, the contribution of any parameter loading from bank material was less than three percent of the load measured at the stream mouth. Phosphorus contributions were higher, accounting for 4.7 percent of the Canaseraga Creek and 9.8 percent of the Catka Creek load. Available phosphorus contributed was 0.3 percent and 0.08 percent of the total load for Canaseraga and Catka Creeks respectively.

10.7.9 Evaluation of the Bogardi T-3 Bedload Samplers (Zimmie, Park and Floess, 1976)

The Bogardi T-3 Bedload Sampler was laboratory calibrated, and compared to the Helley-Smith type sampler. The Bogardi T-3 Bedload Sampler was found to be 40 percent efficient in removing bedload in flume calibration tests. Field measurements were compared with bedload formulae. Bedload was shown to contribute approximately ten percent of the total sediment load in the stream tested.

10.7.10 Surficial Geology of the Genesee Valley

Far from being an ideal valley system developed as a well integrated and consistent geomorphic unit by normal fluvial processes, the Genesee Valley links reaches which have had diverse origins and dissimilar histories. Understanding of present processes and characteristics of the diverse reaches requires knowledge of past conditions.

The inheritance from Pleistocene glaciation accounts for marked contracts in valley form, and continues to exercise long-term control on patterns of subsequent fluvial modification. During late Wisconsinan retreat, the continental ice sheet imponded a succession of proglacial lakes in the Genesee Valley. Draining across the lowest divide freed by the retreating ice, the lakes abandoned the lower northward end of the Genesee Valley in progressively more recent times. The late succession in New York begins with Wellsville Lake, imponded perhaps 19,000 years ago during late Woodfordian time (Almond Glaciation), and extending

from the State Line north to Belmont. South of Rochester, the final imponding involved the Pinnacle Hills Moraine, built approximately 12,000 years ago. Moraine or drift barriers continued local imponding just south of Prtageville, Fowlerville and Rochester, respectively, for a few mi-lennia following deglaciation. It was on this progressively uncovered valley floor that postglacial fluvial erosion began, at different times and in a different manner as dictated by late glacial history.

Prehistoric fluvial development of the floor of the Genesee Valley generally involved transformation of inherited glacial and lacustrine features toward fluvial equilibria. Upstream ends of inherited lake basins were aggraded. Progressive incision of their outlets simultaneiously contributed to their destruction. Steeper reaches, notably the Letchworth Gorge were rapidly eroded, with the debris aggrading downstream where gradient diminished and the valley floor opened out. In alluvial reaches, stream gradient and channel patterns developed long-term equilibrium under previaling load and discharge conditions which reflect coarseness and abundance of load as well as bank coherence. Relationships of dated archeologic sites and radiocarbon analysis of buried wood fragments afford scattered datum points for estimating rates of floodplain modification.

Although modern fluvial processes have only begun to transform the inherited characteristics of the valley as a whole, they are dominant in controlling channel character and development of the valley floor. Two main sediment sources for stream load are material delivered by tributaries and material eroded from the channel perimeter. Cobble and boulder-sized material in the stream bed is derived either from tributaries flowing on steep gradient across bedrock valley walls, or from sharply incising reaches where the stream in downcutting encounters bedrock or glacial till. Downstream from the Mount Morris delta/fan, coarse clastic material moves only gradually and for short distances in the stream bed. Upstream from Portageville however, channel cross section is more open, channel storage is less, channel pattern shows a tendency to braid and gradient is generally steeper than below Mount Morris. In short, the equilibrium among hydraulic parameters is adjusted to handle coarser bedload than in the reach below Mount Morris.

11. DATA INTERPRETATIONS AND CONCLUSIONS

11.1 Causes and Sources of Pollutant Contributions

Large spatial variations in unit loads and concentrations of the three PLUARC study pollutants (phosphorus, chloride and sediments) were found. Detailed interpretation of the data implies that this variation is due as much to soil type and natural geochemical factors as to land use. Since given land uses follow soil type and geological patterns, many studies mistakenly characterize land use as contributing high unit loads when in fact, soil type and geochemical factors are as significant a cause.

In the Genesee River Basin, three types of land areas have characteristically high unit loads of the pollutants studied: 1. Intensive agricultural areas are on calcareous soils in the central to north section of the Genesee Watershed. These areas contribute higher unit loads of phosphorus, suspended solids and chloride than the remainder of the drainage basin. 2. Cultivated mucklands contribute high unit loadings of phosphorus, and 3. Salt mining areas contribute high unit loadings of chloride.

11.2 Extent of Pollutant Contributions in Unit Area Loadings and Seasonal Variations

Unit loadings and seasonal variations found in this study are given in Figures 8-10 and Table 6. A variety of other unit loadings for the Genesee watershed have been published elsewhere (Hetling et al., 1975). Seasonal variation in all parameters indicates the importance of the winter-spring period of the hydrologic year. This observation may influence the nature of remedial measures in any area.

11.3 Relative Significance of Sources Within the Watershed

Because of the highly variable nature of the Genesee watershed, relative contributions from individual sources (point source, urban areas, intensive agricultural, etc.) are small. Thus, attempts to isolate sections of the watershed, where control measures will significantly reduce total loadings to the lake, are frustrating. Areas with high unit loadings have been discussed in 11.1 above.

11.4 Transmission of Pollutants

Attempts at conclusive determinations of delivery ratios have been unsuccessful. There is a general, but variable, increase in unit loadings as one proceeds from the upper reaches of the drainage basin to its mouth. This makes it difficult to interpret changes in the main stem loadings since it is not clear if the changes are due to changing unit loadings for that section of the stream or changes in stream delivery ratios. There are, however, some stream reaches where the gross stream loads decrease; thus, a delivery ratio (at least during the two-year sampling period) is less than one.

11.5 Data Transferability

Generalized results are transferable but the variability found indicates that specific numerical results are unique to an area. Unless a watershed with similar land use practices, soil types and geology can be identified, the results cannot be transferred. This limits extrapolation to very small areas where specific numerical results can be transferred or very large areas where generalized qualitative results can be transferred.

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